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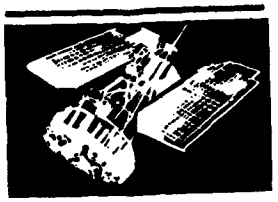

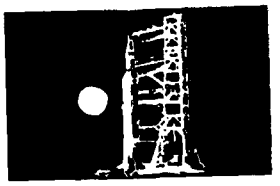

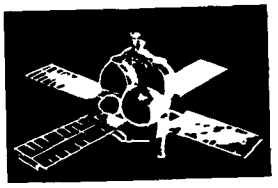

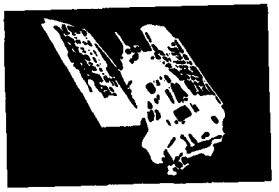

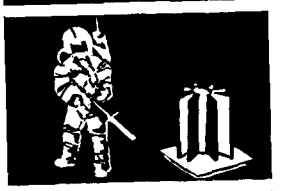

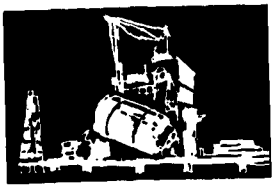

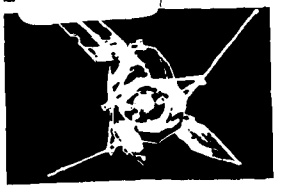

(NASA-CR-124260) STUDY FOR IDENTIFICATION OF BENEFICIAL USES OF SPACE, PHASE 1. VOLUME 1: EXECUTIVE SUMMARY Final Report (General Electric Co.) ~~25~~ 23 p HC $3.25 CSCL 05C G3/34

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STUDY FOR IDENTIFICATION OF BENEFICIAL USES OF SPACE

(PHASE I)

FINAL REPORT - VOLUME I
EXECUTIVE SUMMARY

CONTRACT NAS8-28179

DECEMBER 10 1972

SUBMITTED PER DPD #296,
DR #MA-04

GENERAL ELECTRIC

STUDY FOR

IDENTIFICATION OF

BENEFICAL USES OF SPACE (B.U.S.)

(PHASE I)

CONTRACT NAS8-28179

FINAL REPORT - VOLUME I

EXECUTIVE SUMMARY

December 10, 1972

Submitted Per DPD #296, DR #MA-04

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PREFACE

This Final Report on Phase I of the Study for Identification of Beneficial Uses of Space (B.U.S.) is comprised of two volumes:

Volume I – Executive Summary

Volume II – Technical Report

Volume II is further subdivided:

Book 1 – Section I, Introduction; through part of Section III, Specific Study Results.

Book 2 – Remainder of Section III, Specific Study Results; through Section IV, Conclusions and Recommendations.

Book 3 – Section V, Appendices A through F.

Book 4 – Section V, Appendices G through N.

Phase I of the Study was conducted from December, 1971 to December, 1972 by General Electric's Space Division under contract from the Marshall Space Flight Center. Ninety-one working meetings were held with over 400 individuals representing a broad spectrum of U.S. technological capabilities. Participating commercial industries covered such diverse businesses as Aircraft, Building, Chemicals, Electrical Equipment and Utilities, Food, Metals, Paper, Petroleum, etc. Government agencies, universities, and research institutes have also contributed by providing support in such areas as Health, Oceanography and Economics. The methodology employed in gaining and maintaining this technological support and the results of this effort are reported herein.

These participants intially identified over 100 ideas for potential products, processes and services which might advantageously be developed or produced in space facilities. Further analysis reduced the number of ideas by an order of magnitude, with those remaining representing a wide variety of technologies, ranging from high specificity separation techniques, tungsten x-ray targets, and surface acoustic wave components, to testing of prototype fractional horsepower electric motors.

The last page of this document is printed as a foldout to enable easy referral to short descriptions of each of the key ideas identified in the study.

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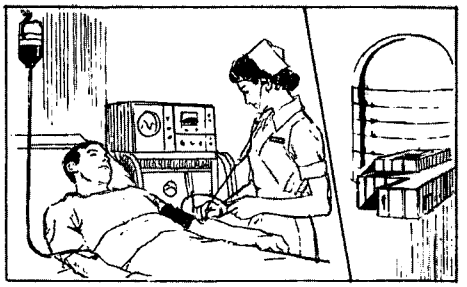

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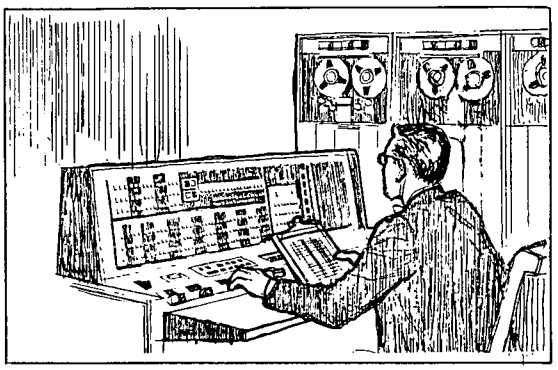

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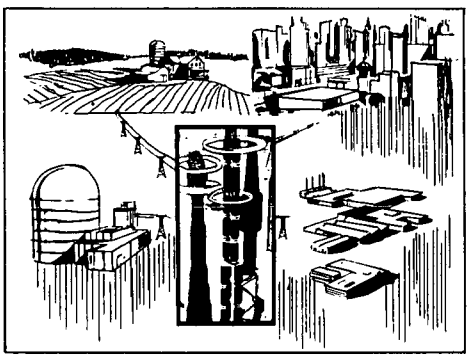

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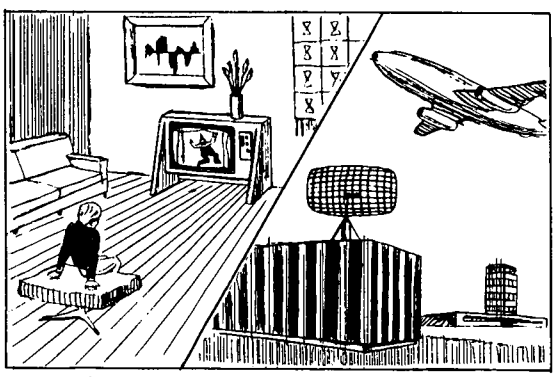

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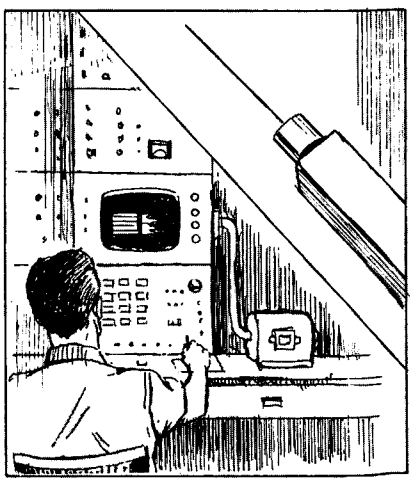

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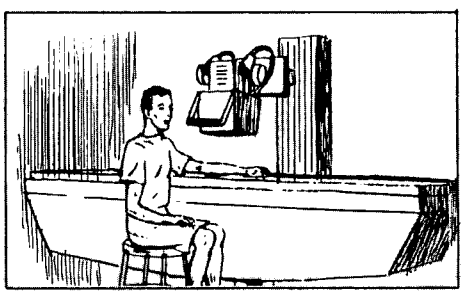

TUNGSTEN X-RAY TARGETS

I INTRODUCTION

Recent decisions and actions to implement plans for the Space Shuttle, as well as the rationale for that transportation system are tangible evidence of the maturing development of the United States Space Program.

The Shuttle's introduction of safe, economical, and frequent access to the unique environment of space will place space in the same context, for the industrial community, as a new instrument, a new laboratory, a new machine, or new factory – a resource of previously unavailable capabilities to develop or produce new products, processes or services. This Study is an initial compilation of such products, processes and services that have been identified by specific organizations whose future operations are linked to new and/or better products, processes and services which offer economic and sociological benefits to the public.

I.1 STUDY BACKGROUND

Over the past fifteen years, the "properties" of space, Figure 1, have been explored by various organizations for possible useful applications. Successes have been scored in the areas of communications, weather observation, and earth resources surveys, all of which hinge, basically, on the synoptic view "property." Until very recently, the other "properties" have been largely bypassed. A slowly growing six-year effort by NASA-MSFC and a few industrial organizations, however, has developed understanding, approaches and experimental equipment related to utilizing other properties, notably zero "g", in studies of basic material sciences, as well as in processing techniques and equipment for applications in space(1).

NATURAL	INDUCED
HARD VACUUM	ZERO "G"
UNFILTERED SOLAR RADIATION	PARTIAL "G"
PARTICULATE RADIATION	INTERMITTENT "G"
UNLIMITED VOLUME AND DIMENSIONS	REENTRY AERO-THERMO CONDITIONS
ISOLATION FROM TERRESTRIAL DISTURBANCES	
SYNOPTIC VIEW	
"BLACK BODY" SINK	

Figure 1. Typical Properties of Space

Such results have led to the realization that a potential exists for advancing from scientific experimentation in space to industrial, possibly commercial, exploitation – the production of new and/or improved products, operation of new and/or improved processes, provision of new and/or improved services.

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(1) Wuenscher, H. F., "Manufacturing in Space," Aeronautics and Astronautics, September, 1972

(2) , "Manufacturing Technology Unique to Zero Gravity Environment", NASA-MSFC Symposium, November, 1968

(3) , "Space Processing and Manufacturing", Symposium Papers, NASA-MSFC, October, 1969

Accordingly, two national symposia were convened by NASA in 1968 and 1969, at which the results(2,3) of analyses, development of concepts, and designed experiments were reviewed for large groups of invitees. In this manner, NASA was able to establish a communication link with technical representatives from a wide spectrum of industries, laboratories, universities and governmental agencies, all generally involved in the non-aerospace sectors of technology. It was hoped that the attendees would, in the interests of their organizations' products, processes, or services, generate specific applications for subsequent exploitation. While results of the symposia were rewarding in terms of increased interest and activity in the aerospace and the scientific communities, as well as in definition of key experiments, there was a singular lack of response from the non-aerospace community.

Thus, while aerospace technologists, especially those at NASA-MSFC, continued uncovering new space processing techniques, analyzing their generic capabilities, defining experiments to verify their approaches, and carrying out key experiments, there remained the critical missing element – finding the Users – the specific non-aerospace organizations who could apply the techniques to develop or produce specific products, processes or services for the public.

Consequently, GE undertook to search out such Users in "A Study for Identification of Beneficial Uses of Space." In essence, this Study involved the utilization of a GE Aerospace Team, backed by the wide spectrum of GE's non-aerospace business units, to devise and exercise a methodology which would gain and maintain the interest and participation of non-aerospace organizations in identifying specific products, processes, and services of value to the public, Figure 2.

IDENTIFY PRODUCTS, PROCESSES OR SERVICES THAT WILL BE BEST DEVELOPED OR PRODUCED IN THE UNIQUE ENVIRONMENT OFFERED BY FUTURE SPACECRAFT

AND WILL BE USED DIRECTLY ON EARTH.

Figure 2. Study Theme

Two early, key decisions were made which contributed to the worth of the Study:

1. To seek the participation of a large number of organizations which could identify with a wide spectrum of products, processes, or services, either as producers or consumers, or, more generally for this Study, as "Users".
2. To conduct the Study primarily via initiating and maintaining dialogs between the Study Team and Key Individuals from potential User organizations.

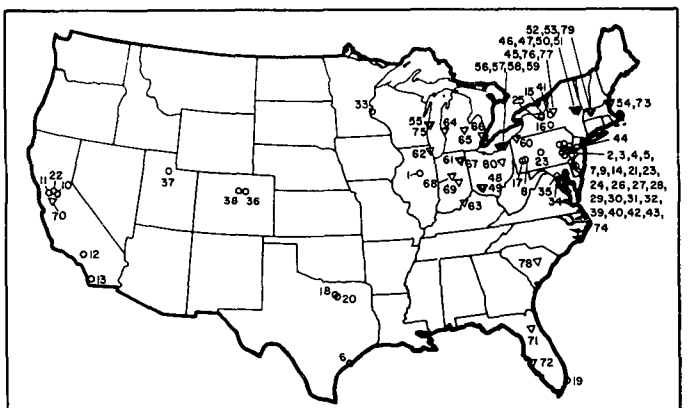
I.2 STUDY RESULTS AND CONCLUSIONS

Our results attest to the success of the Study.

Methodology. Firstly, we gained the participation of 80 Organizations, Figure 3, which resulted in dialogs with 403 Key Individuals. From those contacts, 120 ideas were noted, of which more than 100 were specific, technically applicable to the Study, and of sufficient interest to the Key Individuals to encourage their further consideration and continued dialogs.

Ideas Developed. During the course of the Study, data on 12 of the ideas were sufficiently developed through critical evaluation and analyses to warrant their consideration as prime examples of potential Beneficial Uses of Space, Figure 4. For each of these, specific Key Individuals representing specific User organizations have identified themselves with the ideas, and have performed, or aided in performing significant analyses to derive information required in the Study.

An additional 12 of the identified ideas appear worthy of future consideration. Of the more than 120 ideas noted, only



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2. PRINCETON ORGANICS, INC., PRINCETON, NEW JERSEY
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79. BUSINESS AND PLANNING OPERATION, POWER GENERATION DIVISION, PITTSFIELD, MASSACHUSETTS
80. LAMINATED PRODUCTS DEPARTMENT, COSHOCTON, OHIO

Figure 3. Major Organizations Which Participated in the Study

IDEA NO.*	SUBJECTS	IDEA NO.*	SUBJECTS
1	IMPRINTING CIRCUITRY ON CRYSTAL WAFERS FOR SURFACE ACOUSTIC WAVE ELECTRONICS	42	PRECISE SEPARATION OF RADIO ISOTOPES
3	PARTICLE MANIPULATION BY SMALL FORCES	46	SILICON CRYSTAL GROWTH
5	VIBRATION TESTING OF SMALL MOTORS	59	EPITAXIAL GROWTH OF MAGNETIC BUBBLE MEMORY CRYSTALS
6	SINGLE CRYSTAL AND EUTECTIC HIGH TEMPERATURE TURBINE BUCKETS	60	AMORPHOUS GLASSES AND REFRACTORIES
30	HIGH PURITY TUNGSTEN X-RAY TARGETS	84	BASIC HEAT TRANSFER DATA
		89	SEPARATION OF ISOENZYMES
		96	UTILIZATION OF BIORHYTHMS

* NUMBERS FOR REFERENCE PURPOSES ONLY

Figure 4. Ideas Carried Through Complete Study

45 could, with certainty, be discarded for technical cause, and 26 for miscellaneous non-technical causes, leaving nearly 25 ideas for which insufficient data were obtainable for analysis.

Benefits. A conservative identification of specific benefits potentially accruing from implementation of each of the 12 prime ideas has been attempted. Where estimates were possible, for example, gross potential dollar values of products and services may amount to nearly a billion dollars per year, gross potential reduction in the balance of payments deficit could be nearly half a billion dollars per year, and consumer dollars saved could easily exceed a hundred million dollars per year. Social benefits show, typically, the possibility of thousands of lives saved through early diagnosis of certain illnesses, while the potential for therapy appears to hold promise of an undeterminable increase in the level of public health. In addition, a number of areas of military benefit have been noted without attempting further definition.

Conclusions. In all, it appears that the Study has produced the desired results:

1. A methodology which opens two-way communications between the aerospace and non-aerospace sectors of industry, and thereby can gain and maintain User support for the space applications program.

2. Ideas for space-developed or -produced products, processes, and services which are backed by meaningful data.

3. Preliminary estimates of the benefits which could accrue from such products, processes, and services.

4. A major conclusion, not suspected at the outset of the Study, is that the commercial sector of industry is at least as concerned, if not more concerned, with the legal/administrative/financial business problems associated with commercial space ventures as it is with the technical.

II STUDY OBJECTIVES

Guided by the aforementioned theme, the Study was aimed at fulfilling the following objectives:

1. Identification of specific organizations that could be Users of space-obtainable knowledge and capabilities, which can contribute to the development or production of products, processes, or services for the public.
2. Identification of the specific knowledge and capabilities required by the Users to solve problems in such development or production.
3. Establishment of support by specific Users for programs which provide solutions to their specific problems.
4. Assessment of potential benefits, and identification of potential impacts, accruing from such solutions.

II.1 IDENTIFICATION OF SPECIFIC USERS

In this and the subsequent two objectives, a keyword is "specific". In previous reports, papers, and meetings and in analyses of processes or equipment concepts there was rarely an indication of what specific organization(s) required what specific problem solved in order to develop or produce what specific product, process or service. It was also implicit in this objective that the preponderance of Users to be involved in this Study should be selected from areas outside the aerospace business.

The results documented herein confirm that we have met that objective. For instance, of the more than 120 ideas noted during the study, over 90 percent were identified by individuals in 72 non-aerospace organizations located in 19 states and ranging in size from 25 employees to those whose research staffs alone number in the hundreds. For over 60 percent of the ideas, individuals were willing and able to dialog their problem areas in depth with us, and also agreeable to their organizations' identification with those ideas which extended from antibiotics to welding and from vibration testing to amorphous glasses.

II.2 IDENTIFICATION OF SPECIFIC REQUIRED KNOWLEDGE/CAPABILITIES

The intent here was to pin down the specifics of what was needed from space operations by the User in order to resolve the problems, provide the needs, or settle the critical issues which inhibit his achieving his specific goals and objectives.

Dialogs between the space-oriented Study Team and the product, process, and service-oriented Users resulted in the successful accomplishment of the objective. Typically, the search for specifics, conducted in an atmosphere of mutual support, by the Study Team and User personnel identified knowledge requirements (Figure 5) that ranged from heat

IDEA NO.		ISSUES, NEEDS, AND PROBLEM AREAS	REQUIRED KNOWLEDGE/CAPABILITIES
1	IMPRINTING CIRCUITRY ON CRYSTAL WAFERS FOR SURFACE ACOUSTIC WAVE ELECTRONICS	ELIMINATION OF VIBRATION FROM IMPRINTING SYSTEM	DECOUPLED PLATFORM FOR MOUNTING IMPRINTING SYSTEM (e.g., ELECTRON BEAM GUN) WHICH ELIMINATES SEISMIC VIBRATIONS, ACOUSTIC COUPLING.
3	PARTICLE MANIPULATION BY SMALL FORCES	ELIMINATION OF GRAVITY MASKING EFFECT	FACILITY WHICH ELIMINATES OR COUNTERBALANCES GRAVITY FORCE SO AS TO ENABLE A VARIETY OF MICRO-FORCE INDUCERS (e.g., LIGHT, HEAT, SOUND, RF, ETC.) TO ACCELERATE PARTICLES IN VARIOUS MEDIA.
5	VIBRATION TESTING OF SMALL MOTORS	IMPROVEMENT OF PRESENT 4 CPS LIMIT, ISOLATION FROM SONIC AND MAGNETIC FIELDS	DECOUPLED PLATFORM FOR MOUNTING PROTOTYPE MOTORS AND VIBRATION-MEASURING INSTRUMENTATION (e.g., LASER HOLOGRAPH) WHICH ELIMINATES SEISMIC VIBRATIONS AND ACOUSTIC COUPLING.
6	SINGLE CRYSTAL AND EUTECTIC HIGH TEMPERATURE TURBINE BUCKETS	CERTAIN SUPERALLOYS NOT AMENABLE TO CASTING; PRESENT CRYSTALS SMALL AND CONTAIN DISLOCATIONS; EUTECTICS CONTAIN DISLOCATION, ETC.	FACILITY TO MELT SUPERALLOYS, REFRACTORY METALS, EUTECTICS WITHOUT CRUCIBLE; GROW LARGE CRYSTALS ALONG SPECIFIC PLANES, WITHOUT INTERNAL STRAINS, ANOMALIES CAUSED BY CONVECTION, PRODUCE EUTECTICS WITHOUT DEFORMATIONS CAUSED BY CONVECTION; PROVIDE SUPERCOOLING OF SIZEABLE SPECIMENS AFTER CRUCIBLESS MELT
30	HIGH PURITY TUNGSTEN X-RAY TARGETS	CONTAMINATION OF MELT BY CRUCIBLE	FACILITY TO MELT TUNGSTEN WITHOUT CRUCIBLE, PROVIDE SUPERCOOLING OF SIZEABLE AMOUNT AFTER CRUCIBLESS MELT
42	PRECISE SEPARATION OF RADIOISOTOPES	HIGH SPECIFICITY SEPARATION TECHNIQUE	FACILITY WHICH ELIMINATES BUOYANCY, PRECIPITATION, CONVECTION FORCES; ALLOWS SMALL FORCES TO ACCELERATE ISOTOPE PARTICLES AT RATES RELATED TO SMALL DIFFERENCES BETWEEN ISOTOPES.
46	SILICON CRYSTAL GROWTH	CONVECTION DURING CRYSTAL GROWTH	CRYSTAL-GROWING FACILITY WHICH DECREASES CONVECTIVE FORCES IN MELT TO MINIMIZE NON-UNIFORMITIES IN DOPANT DISTRIBUTION, THUS INCREASING UNIFORMITY OF CRYSTAL ELECTRICAL PROPERTIES; ALSO TO GROW LARGER CRYSTALS.
59	EPITAXIAL GROWTH OF MAGNETIC BUBBLE MEMORY CRYSTALS	CONVECTION, LOSS OF SUPERSATURATION	EPITAXIAL CRYSTAL-GROWTH FACILITY TO ELIMINATE CONVECTIVE CURRENTS THAT CAUSE THE NON-UNIFORMITIES IN TEMPERATURE AND SATURATION LEADING TO NON-UNIFORMITIES IN FILM THICKNESS AND MAGNETIC PROPERTIES; ALSO TO GROW LARGER AREA CRYSTALS.
60	AMORPHOUS GLASSES AND REFRACTORIES	CRYSTALLIZATION DUE TO INCLUSIONS, CONVECTION	FACILITY TO MELT AND SUPERCOOL GLASSES AND CERTAIN OXIDES WITHOUT DEVITRIFICATION CAUSED BY CRUCIBLE SURFACES, CONVECTIVE CURRENTS, INCLUSIONS.
84	BASIC HEAT TRANSFER DATA	CONVECTION DURING MEASUREMENTS	DATA ON THERMAL CONDUCTIVITY OF LIQUIDS (ESPECIALLY OILS) IN ABSENCE OF CONVECTION
89	SEPARATION OF ISOENZYMES	DENATURATION OF ISOENZYMES BY SEPARATION UNDER G LOADING	FACILITY TO SEPARATE ISOENZYMES WITH VERY WEAK FORCES SO AS TO AVOID DENATURATION WHICH OCCURS WHEN SEPARATION REQUIRES LARGER FORCES (e.g., WHEN PERFORMED IN ONE G)
96	UTILIZATION OF BIORHYTHMS	TERRESTRIAL INFLUENCES	DATA ON PHYSICAL AND BEHAVIORAL WELL BEING OF SUBJECTS WHEN POTENTIAL INFLUENCES (e.g., LUNAR, MAGNETIC, GRAVITY, ETC.) ON BIORHYTHMS ARE VARIED. FOR USE IN POSSIBLE MODIFICATION OF DIAGNOSIS, THERAPY, WORK CYCLES.

Figure 5. Required Knowledge/Capabilities

transfer data to physiological and psychological data, while capability requirements ranged from zero "g" facilities to vibration-free platforms.

II.3 ESTABLISHMENT OF SPECIFIC USER SUPPORT

The involvement of non-aerospace Users in the Study was further strengthened by meeting this objective. Several organizations contacted during the Study commented unfavorably on the "one-shot" involvement that had occurred in earlier attempts to interest them in space processes.

Our method of meeting this objective was not only to determine specific interests of Users, but also, through continued dialogs with them, to probe the details of that interest, and to enlist their aid in analyzing their problems. The crux of this method was to encourage the Users to perform actual analyses in worthwhile areas, Figure 6. For such User support, we were able to offer token financial remuneration. In several cases, User organizations did agree to supply such analyses, and to accept small subcontracts. More significantly, a few organizations provided the desired analyses without funding.

ANALYSIS SUBJECT	USER ORGANIZATION
PARTICLE MANIPULATION BY SMALL FORCES	GE - CORPORATE RESEARCH & DEVELOPMENT
IMPRINTING OF CIRCUITRY FOR SURFACE ACOUSTIC WAVE COMPONENTS	GE - ELECTRONICS LABORATORY
ACCURATE SEPARATION OF ISOENZYMES	POLYSCIENCES, INC.
BENEFITS OF SINGLE CRYSTAL TURBINE BUCKETS	
TO AIRLINES	EASTERN AIRLINES
TO PUBLIC	DREXEL UNIVERSITY
TO MANUFACTURER	GE - AIRCRAFT ENGINE GROUP
HIGH PURITY TUNGSTEN X-RAY TARGETS	GE - MEDICAL SYSTEMS DIVISION
VIBRATION TESTING OF FRACTIONAL HORSEPOWER ELECTRIC MOTOR PROTOTYPES	GE - APPLIANCE COMPONENTS LABORATORY
AMORPHOUS GLASSES AND SINGLE CRYSTAL GARNET FILMS	CORNING GLASS WORKS
UTILIZATION OF BIORHYTHMS	UNIVERSITY OF MINNESOTA, NATIONAL INSTITUTES OF HEALTH

Figure 6. Typical Analyses by Users

Another aspect of User support we attempted to establish during the Study was to develop spokesmen for space development or production. In this, the results can presently be considered moderately successful. A number of Key Individuals have indicated that they now understand the potential opportunities in their areas of interest. On the other hand, while commitments to pursue specific programs, or to expend specific funds on space development or production programs would have been welcomed, the general attitude among Users was that more study on the business and technical problems was required before substantial commitments could be made.

II.4 ASSESSMENT OF POTENTIAL BENEFITS, IDENTIFICATION OF IMPACTS

Here, the question is being asked, "If space development or production could resolve the problems, settle the issues, or provide the needs defined by the User, what specific value would the resulting product, process or service have? Furthermore, what disadvantages might accrue?"

A complete analysis of value, or benefits must account for all the potential beneficiaries. For example, in the case of a new material or a better component, which subsequently are processed into a manufacturer's parts, then into a fabricator's equipment, which later are operated to perform a service for the public, there can be a chain of several "Users" all of whom derive certain benefits, as exemplified in Figure 7. The limitations of effort on this Study have precluded analyzing every link in the User chains involved in all the worthwhile ideas of the Study. However, benefits to key Users are given for all such ideas. It must be noted that, by terms of the guidelines for this Study, we did not account for the cost to achieve such benefits. Therefore, all economic benefits must be considered as gross values.

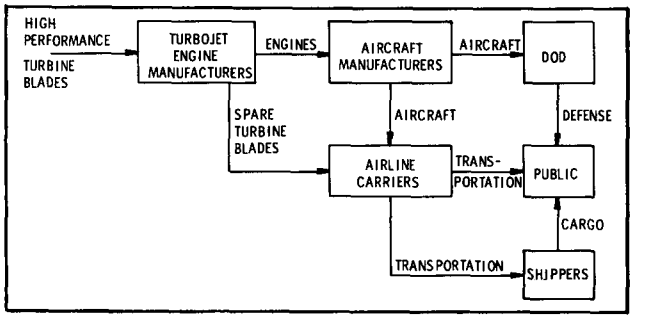

Figure 7. Typical Hierarchy of Users – Space Processed Turbine Blades

A further point on benefits: the User will often be faced with alternative advantages offered by a new product, process or service. Since different benefits may evolve from the choice of alternatives, a complete analysis must account for those choices. Again, we have demonstrated this point in selected cases, as shown for example in Figure 8.

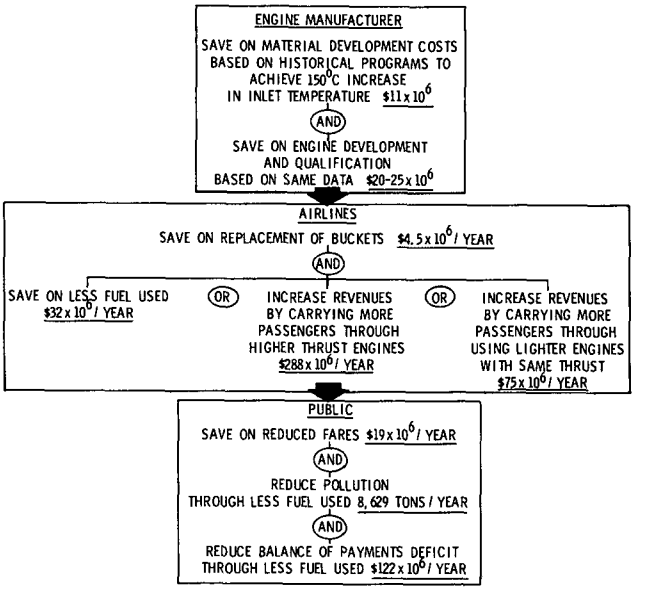

Figure 8. Typical Benefits – Extract from Analysis of Single Crystal and Eutectic Aircraft Turbine Buckets

Finally, while, in many cases, benefits may be expressed in monetary values, there are products (mainly medical), processes, and services which produce benefits not meaningfully measurable in dollars. These include for example, the decrease in pollution from higher temperature turbine buckets, the quieter appliance motors, the safety of purer medical radioisotopes, etc.

Disadvantages of potential space-developed or -produced products, processes, and services are of concern in this objective, because of past experience with other "beneficial" products. Detergents, phosphates, insecticides, preservatives, and other earth/air/water pollutants have sensitized the public to technology's mixed blessings. What is sought in this objective is early indication of possible difficulties. Only in the high temperature turbine blades have we found such a possibility, the increased production of certain oxides of nitrogen due to higher temperature combustion. In this case, there is the mitigating consideration of better emission control devices under development in several laboratories.

III RELATIONSHIP TO OTHER NASA EFFORTS

In dialogs with potential Users and in presentations on this Study we have stressed the fact that the Study and its results are not isolated, independent entities, but rather steps in a progression of mutually supportive efforts. The primitive high altitude explorations of the 1950's, the space investigations of the 1960's, the initial space applications studies of the 1970's are examples of predecessor efforts that have contributed to the state-of-the-arts involved in ideas of this Study. Contemporary programs have also benefited, and will benefit from, this Study. Finally, plans for future programs have influenced decisions and approaches utilized in this Study. Figure 9 lists typical NASA efforts identified by the NASA C.O.R. as related to this Study.

III.1 FUTURE SPACE PROGRAM PLANS

While the study was not constrained by availability of flights in the current traffic profile defined by NASA Headquarters, general guidelines were requested and obtained from the NASA C.O.R., concerning future NASA programs. These proved useful in framing realistic time phasing alternatives for implementing the ideas derived in the Study. An example of these guidelines is the availability of the Space Shuttle in 1979, with limited experimental payload capacity during the early developmental flights.

The results of B.U.S.-related investigations will undoubtedly affect experiments planned for scientific disciplines, and vice versa. Therefore, it will be advantageous to plan the scientific experiments taking into consideration the needs in application areas that are the subject of this study. A similar relationship exists with respect to some of the planned space technology experiments. For instance, the results of investigations on particulate concentrations about the spacecraft and possible countermeasures to eliminate optics contamination will be important in designing the systems for B.U.S.-related applications requiring extreme contamination-free environments. Conversely, the development of precise location mechanisms for levitation melt processes may also be useful in scientific experiments involving levitated equipment.

III.2 SPACE SHUTTLE

All dialogs carried on during the Study have stressed the fact that the shuttle will be the key to future space applications. Based on current and, hopefully, increased future publicity regarding the frequency, reusability, and economy of shuttle transportation, we have, we believe, instilled in the minds of some Users the reality and businesslike aspects of shuttle operations. On that basis, potential Users have begun to overcome the negative implications of "one-shot systems" and high costs associated with forerunner space programs.

TITLE	SPONSORING CENTER	PERFORMING ORGANIZATION	CONTRACT NO(S).	PERIOD OF PERFORMANCE	OBJECTIVES	PRESENT STATUS	KEY RESULTS
1. FUTURE SPACE PROGRAM PLANS	HEADQUARTERS	ALL CENTERS	MANY	CONTINUING	INTEGRATED PROGRAM OF SCIENTIFIC, TECHNOLOGICAL, AND APPLICATIONS EXPERIMENTS, TESTS, OPERATION	PLANS FOR DEDICATED AUTOMATED SPACECRAFT, SKYLAB, ASTP, SHUTTLE ENGINEERING ARE SOMEWHAT FIRM. SHUTTLE FLIGHTS AND BEYOND-NOT DEFINED SUFFICIENTLY FOR DEFINITIVE USE IN THIS STUDY	FUTURE SPACE PROGRAM PLAN - AVAILABILITY OF ACCOMMODATIONS FOR OTHER PAYLOADS NOT DEFINED
2. SPACE SHUTTLE	MSC	NORTH AMERICAN ROCKWELL	NAS9-1400	8/72 - CONTINUING	DEVELOP THE SPACE SHUTTLE	IN EARLY PHASE C	VARIOUS DOCUMENTS ISSUED BY FUTURE PROJECTS OFFICE, PAYLOAD PLANNING GROUP, ETC. NONE APPROVED FOR THIS STUDY.
3. ELECTROPHORETIC SEPARATOR FACILITY	MSFC	GE	NAS8-24793, NAS8-27797, NAS8-28365	8/69-10/72	EXPERIMENTS ON APOLLO 14 & 16 TO DEMONSTRATE FREE FLOW ELECTROPHORETIC SEPARATION. TO GAIN EXPERIENCE FOR DESIGN OF FUTURE FLIGHT EQUIPMENT.	EXPERIMENTS PERFORMED. LIMITED SUCCESS IN ACCOMPLISHING OBJECTIVES.	SUBSTANTIATION THAT CERTAIN POTENTIAL HIGH VALUE BIOLOGICALS ARE REQUIRED IN QUANTITIES AND PURITIES NOT ACHIEVABLE BY PRESENT METHODS. FREE FLOW ELECTROPHORETIC SEPARATION IN SPACE APPEARS FEASIBLE TO OBTAIN SUCH MATERIALS.
					EXPERIMENT M-570 ON SKYLAB. TO FURTHER DEMONSTRATE PRINCIPLES AND TO PERFORM FIRST SEPARATION OF BIOLOGICAL MATERIALS.	FLIGHT OBJECTIVES DISCONTINUED. EFFORT RE-ORIENTED TO GROUND-BASED R&D.	
4. ECONOMETRIC ANALYSIS OF CRYSTAL GROWTH IN SPACE	MSFC	GE	NAS8-27942	9/71-7/72	ASSESS STATUS OF ELECTRONIC SINGLE CRYSTAL PRODUCTION & PROJECT FUTURE REQUIREMENT. FORECAST REVENUES, COSTS, PROFITS TO INDUSTRY TO MEET PROJECTED REQUIREMENTS. COMPARE VALUE OF SPACE PRODUCTION VERSUS TERRESTRIAL PRODUCTION.	ANALYSIS COMPLETE. FINAL REPORT ISSUED.	SOPHISTICATED COMPOUND SINGLE CRYSTALS APPEAR TECHNICALLY AND ECONOMICALLY JUSTIFIED FOR SPACE PRODUCTION. SINGLE SILICON CRYSTALS OF CURRENT SIZE AND SHAPE APPEAR NOT JUSTIFIED FOR SPACE PRODUCTION.
5. LEVITATION MELTING FACILITY	MSFC	GE	NAS8-24683, NAS8-26157, NAS8-27228	6/69-10/72	DEVELOP FACILITY FOR CRUCIBLESS MELTING AND SOLIDIFICATION. PRIMARILY FOR METALLURGICAL RESEARCH & DEVELOPMENT.	COMPLETED. ACHIEVED OBJECTIVES	MOST PROMISING EXPERIMENTAL AREAS IDENTIFIED. APPROACHES EVALUATED. DESIGN CONCEPT ESTABLISHED.
					PROTOTYPE DEVELOPMENT.	EQUIPMENT READY FOR DEMONSTRATION	GROUND DEMONSTRATION OF POSITIONING CONTROL. MATERIALS WITH NEW PROPERTIES FOUND LIKELY.
6. MATERIALS → PROCESSING	HEADQUARTERS	NATIONAL BUREAU OF STANDARDS	NOT APPLICABLE	1972-1973	EXAMINE GROWTH AND PERFECTION OF CRYSTALS. ESTIMATE EFFECTS OF CONVECTION ON GROWTH.	IN PROCESS.	DEFINITION OF KEY UNKNOWNS IN GRAVITY - FREE GROWTH OF CRYSTALS.
7. SPACE PROCESSING	MSFC	MSFC	NOT APPLICABLE	1966 - CONTINUING	DEVELOP, AND SPONSOR DEVELOPMENT OF, TECHNIQUES FOR DEVELOPING OR PRODUCING PRODUCTS, PROCESSES IN SPACE.	IN PROCESS.	PATENTS, ANALYTICAL DATA, GROUND EXPERIMENTS, DROP TOWER TESTS, AEROBEE EXPERIMENTS, ETC. ON ZERO G PROCESSES.

Figure 9. Other NASA Plans and Programs Related to this Study

III.3 ELECTROPHORETIC SEPARATOR FACILITY

Electrophoretic processing in the space environment has generated wide interest among potential Users as a powerful concept for the production of ultrapure biological materials. Since the free flow method was being vigorously pursued in other studies, it was treated lightly in this Study. On the other hand, the separation of isoenzymes and, possibly, other macromolecules by large pore gel electrophoresis, with its distinct differences from the free flow method was uncovered and carried through the Study (Idea No. 89).

III.4 ECONOMETRIC ANALYSIS OF CRYSTAL GROWTH IN SPACE

This analysis was pertinent to the B.U.S. Study and results were integrated therein, particularly with respect to epitaxial crystal growth (Idea No. 59). Differences of opinions exist as to the future cost of producing garnet bubble memories in space, but the $2,000 to $7,000 per kilogram estimated selling price of such devices is compatible with projected shuttle transportation costs, and the projected savings of $50 million per year in production costs through space production is very attractive to business planners. For current sizes and shapes of silicon crystal components, production costs are low and space processing offers no advantage; however, future space production of much larger crystals or silicon ribbons appear to be economically justified (Idea No. 46).

III.5 LEVITATION MELTING FACILITY

The positive answers achieved under the three listed contracts have lent credence to a number of potential products identified by the B.U.S. study. Key User organizations and Key Individuals have been briefed on available levitation melting results, and have, thus, felt encouraged to pursue the identification of related B.U.S. ideas. For example, the production of high purity tungsten x-ray targets (Idea No. 30) through levitation melting and, possibly, supercooling has so interested GE's Medical Systems Business Division that Key Individuals performed the required initial analyses without cost to the B.U.S. contract.

Phase II B.U.S. activities on such ideas will also benefit considerably; mainly from the viewpoints of defining experiment requirements and preliminary planning of development programs.

III.6 MATERIALS PROCESSING – NATIONAL BUREAU OF STANDARDS

The crystal growth studies conducted by NBS are purely scientific in nature and are not related to any specific practical application, thus, the NBS studies do not overlap with the B.U.S. Study. The dialogs with NBS personnel proved useful in providing the B.U.S. Study with a preliminary insight into the current unknowns concerning the possible effects of a gravity free environment on crystal growth. This information was useful to the B.U.S. Study in establishing the preliminary development steps leading to space operational activities in applications dealing with crystal growth, such as the growth of large germanium crystals for the gamma ray camera (Idea No. 45), and the growth of silicon crystals for power and medical applications (Idea No. 46).

III.7 SPACE PROCESSING AT MSFC

The B.U.S. Study utilized available MSFC results as "seeds" to initiate dialogs with non-aerospace Users. Typically, ideas on crystal growth, high purity refractories, high specificity biologicals, etc., all had their roots in such seeds. As a corollary, unique ideas developed during the B.U.S. Study, such as those on imprinting surface acoustic wave circuitry, particle manipulation, fractional horsepower motor testing, thermal conductivity of liquids, etc., may well evoke some investigation at the above labs.

IV METHODS OF APPROACH AND PRINCIPAL ASSUMPTIONS

IV.1 ASSUMPTIONS AND GUIDELINES

Assumptions and guidelines for the B.U.S. Study were included in the Scope of Work of the contract for the Study. Full authority for such assumptions and guidelines was vested in the Contracting Officer's Representative (C.O.R.) at NASA, MFSC. Several guideline changes were approved by the C.O.R., and with some qualifications, all guidelines were met. Comments on some key guidelines and assumptions are given below.

Guideline III.1. As initial direction, the contractor shall emphasize identification and development of applications in the following User categories:

1. *Manufacture of commercial products unattainable on earth, or for which advantages exist in in-space manufacture.*
2. *Development of new mechanical and chemical processes for application either in space or on earth.*
3. *Production of improved medicines.*
4. *Development of new medical procedures and equipment.*

The NASA C.O.R. advised liberal interpretation of these categories. Thus, the wide variety of processes includes, for example, nuclear and physical processes. Under Item 3, for instance, we include biologicals such as isoenzymes.

Guideline III.4. The initial thrust of the contractors effort is to be internal to his own organization or with organizations with which he has well established working relations. Subsequently, when the required methodology has been adequately developed, the contractor may then, with approval of the C.O.R., approach other industrial firms.

This guideline led to an approximate three-month delay in initiating outside contacts. As we later found, many companies, normally remote from aerospace involvement, required a longer "gestation" period before finding themselves able to generate ideas for the Study. That "gestation" period coupled with the initial three-month delay, then resulted in late entries to our Study results. While we could accommodate some late results by slipping our schedules (with the NASA C.O.R.'s approval), some ideas simply had to be listed "for future consideration".

Guideline III.5. Within the contractor's organization, at least 50 percent of the contractor man-hours shall be expended by personnel outside of the aerospace group. It is absolutely essential that the talents, ability, and expertise of key individuals, representing a wide diversity of potential user areas from outside the aerospace group, actively and directly participate in this study.

This guideline proved exceedingly valuable in uncovering many of the ideas in the Study. The 80 organizations visited during the Study reflect 14 of the basic industries in the U.S. as well as Universities and Government Agencies. Ninety percent of these organizations are from outside the aerospace industry.

IV.2 STUDY APPROACH

The objectives discussed earlier were supported by four tasks, Figure 10, defined in the Statement of Work issued by the NASA C.O.R. as part of the contract for this Study. These tasks were further amplified through intensive discussion with the NASA C.O.R. and other cognizant NASA personnel.

The overwhelming importance of Task 1 is evidenced in the structuring of four major subtasks within that task, the NASA C.O.R. interface within the task, and the number of interfaces between its subtasks and the remaining tasks.

While the logic diagram provided the structure of our Study, it was our method of implementing the logic that was instrumental in providing the significant results. Briefly, the methodology used was – talking! Essentially, we provided a small, space-oriented Core Team, which was called upon to enter into dialogues with individuals and small teams from a broad group of diverse, non-aerospace organizations. The functions of the Core Team were to provide direction to the dialogues and catalytic action to the interplay of space expertise with the expertise of pertinent non-aerospace areas. Through such dialogues we sought to find a "match" between problems inhibiting the development or production of needed non-aerospace products, processes or services, and those space "properties" which might enable solution of the problems.

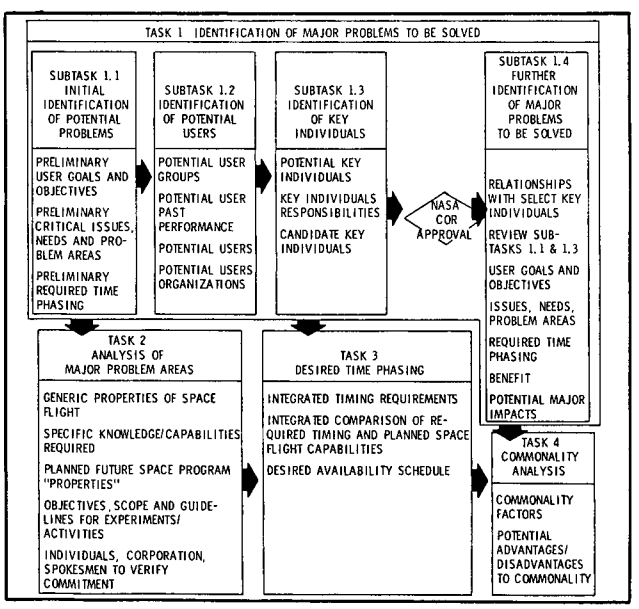

Figure 10. Study Logic

IV.3 TASK SUMMARY

While the dialogs carried on with Key Individuals formed the chief basis of information used in the Study, that technique was supplemented by analyses, carried on by both the Core Team and Key Individuals, and by literature surveys, particularly in the early stages of searching out goals, Users and Key Individuals, Figure 11.

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LYLE, J. M.: REPORT ON SPECIAL SURVEY OF INDUSTRY EXPERIENCE IN THE APPLICATION OF ADVANCED TECHNOLOGY TO CIVIL SECTOR NEEDS; REPORT BY THE RESEARCH AND ENGINEERING ADVISORY COMMITTEE OF THE NATIONAL SECURITY INDUSTRIAL ASSOCIATION, FEB 15, 1972.

———: RESEARCH APPLIED TO NATIONAL NEEDS, NATIONAL SCIENCE FOUNDATION REPORT, 1972.

Figure 11. Source Material for Goals, Objectives, Problem Areas

Task 1.0, Identification of Major Problems to be Solved. Task 1 provided, initially from within GE, subsequently from the complement of participating organizations, 120 ideas for products, processes, and services whose development or production might be expected to evolve problems solvable only, or better, in space facilities.

Subsequent dialogs and analyses carried on in mutually supportive efforts by the Core Team and participating Key Individuals reduced that number by an order of magnitude, and derived the information on required knowledge/capabilities required for subsequent analysis. Along the way, we learned some useful lessons, Figure 12.

Chief among such lessons has been the fact that initiating and maintaining dialogues with selected Key Individuals is an excellent way of eliciting meaningful ideas for products, processes, and services to be developed or produced in space.

Of course, establishing such dialogues often engenders situations or circumstances which are less than straightforward. For example, we learned in several instances that the individuals who had defined certain problems had, because of limitations in the scope of their activities, been unaware of other work which either negated or transfigured those problems. We learned, therefore, to utilize supplementary resources in order to "track down" the real problem and/or the most knowledgeable Key Individual.

We also found several circumstances in which presented ideas were research oriented or otherwise were not related to specific applications. Selected, brief analyses were carried out in certain of these cases, and the results utilized in establishing subsequent dialogues.

CIRCUMSTANCE	B.U.S. SOLUTION	RECOMMENDED ADDITIONAL SOLUTIONS
IDENTIFYING THE REAL PROBLEM AND/OR REAL KEY INDIVIDUAL	TECHNICAL CONSULTATION, ANALYSIS GE CONTACTS, ADVISORY BOARD TRACE THROUGH USER ORGANIZATION	
IDENTIFICATION OF PROCESS OR RESEARCH IDEA WITHOUT APPLICATION	SELECTED ANALYSES ADDITION TO "SEEDS", "CLUES".	IN-DEPTH ANALYSIS
LOWER PERCENTAGE OF IDEAS FROM OUTSIDE GE		
LEVEL OF TOP CONTACT	SELECTED EXECUTIVE CONTACTS	PUBLICIZE PROGRAM, EXAMPLES TO EXECUTIVES
"GESTATION" PERIOD	EXTENDED "FINAL" DATES	INITIATE OUTSIDE CONTACTS AT OUTSET OF STUDY
APPREHENSION (OF GE, NASA)	STATEMENTS ON PROPRIETARY DATA, DIRECT NASA/USER FOLLOW-ON, NASA REVIEW OF RIGHTS-IN-DATA, ETC.	PUBLICIZE PROGRAM, NASA/USER FOLLOW-ON, REVIEW OF RIGHTS-IN-DATA, ETC. BUSINESS PLANNING STUDY
SUBCONTRACTS NOT OF UNIVERSAL INTEREST	TRANSFER OF FUNDS TO INTERNAL TO INCREASE CONTACTS	FLEXIBILITY IN FUNDING ALLOCATION
TIMING - ASAP	TIMING ANALYSIS STARTED FROM "TODAY" RATHER THAN FROM DATE OF NEED	
PROLIFERATION OF BENEFITS, IMPACTS THROUGH USER CHAIN	SELECTED BENEFIT ANALYSIS	SEVERAL SPECIFIC IN-DEPTH BENEFITS ANALYSES
THE DIALOG METHOD OF GENERATING SPECIFIC USER, PROBLEM AREAS WORKS		

Figure 12. Lessons Learned in Performing Task 1.0

Such analyses, supported by introductory information on space "properties", "seed" ideas of potential space processes, and "clues" as to what to look for in their organization's products, processes, and services have provided a large percentage of useful results.

There are also a set of lessons that stem from circumstances that surfaced when it was noticed that fewer ideas were being generated outside GE than inside.

Seeking the solution to this circumstance led to the conclusion that the higher level of contact (Vice Presidents) in GE was an aid, as was the three-month "headstart" which provided GE Key Individuals with a longer "gestation" period for ideas. We attempted to alleviate the first problem by seeking higher level contacts. Future such programs could benefit by publicizing them in various trade media. We also made more "gestation" time available by extending the dates of final contacts.

A conscious choice to contact a maximum number of organizations representing a broad cross section of potential Users resulted in only short times available for interfacing with any one organization. The alternative of selecting few companies and spending more time with them was deemed too high a risk in terms of study results. Such an approach might be worthwhile now that a gross filter has been completed.

Another inhibiting circumstance is felt to be industry's possible apprehension of GE and NASA. We attempted to alleviate this feeling with pertinent statements, but many of their questions need answers. Discussion on this follows in Section VI, Study Limitations.

Most Users identified the need for their ideas as immediate. This circumstance inhibited a meaningful time scheduling task based on need.

The benefits and impacts analyses develop, generally, a number of alternatives available to the User as to how to utilize such benefits. That, coupled with the number of levels in the User hierarchy leads to the circumstance of more permutations than could be carried on in this limited Study. We, therefore, limited our effort to providing several representative analyses, and recommend the possibility of benefits analyses studies in other areas in the future.

Task 2.0, Analysis of Major Problem Areas. Task 2 reduced the issues, needs, and problem areas of Task 1 to the specific knowledge or capabilities required from a space facility to develop or produce the desired products, processes, or services. Those required knowledge and capabilities were then utilized to generate driving requirements and preliminary definition data for experiments and/or space activities.

Subsequently, we attempted to obtain statements on potential commitments by Users in the event of successful experiments/space activities. Such statements, while occasionally verbalized, were not documented.

Key lessons were also learned in the performance of Task 2, Figure 13. While suspected at the beginning of the Study, the lack of User knowledge and/or understanding of space shuttle, automated spacecraft, and their payloads was greater than expected. Considerable explanations and illustrations, shown typically in Figure 14 were added to our original dialogs to overcome this deficiency. More publicity on such subjects, especially related to applications of the types considered in this Study, in appropriate trade and technology media would help alleviate this problem.

CIRCUMSTANCE	B.U.S. SOLUTION	RECOMMENDED ADDITIONAL SOLUTION
LACK OF USER KNOWLEDGE OF SHUTTLE	ADDED SHUTTLE DISCUSSION TO DIALOG	PUBLICIZE SHUTTLE CAPABILITIES IN NON-AEROSPACE TRADE MEDIA
LACK OF USER UNDERSTANDING OF AUTOMATED SPACECRAFT/PAYLOADS	DISCUSSION OF AUTOMATED PAYLOAD CAPABILITIES	PUBLICIZE AUTOMATED SPACE OPERATIONS
WRITTEN COMMITMENTS VIRTUALLY IMPOSSIBLE DATA TOO LIGHT AND SPECULATIVE EXPOSURE TOO SHORT UNANSWERED KEY QUESTIONS	SEEK VERBAL COMMITMENTS	FOLLOW-ON BUSINESS PLANNING WITH USER ORGANIZATIONS TO INVOLVE KEY DECISION-MAKERS

Figure 13. Lessons Learned in Performing Task 2.0

There are at least several reasons why User commitments appear to be difficult to obtain. These reasons all seem to center on the relative brevity and novelty of commercial industry involvement with space as a medium of operation. It is our opinion that much of the difficulty could be overcome by carrying on Business Planning efforts that utilized User decision makers in key roles.

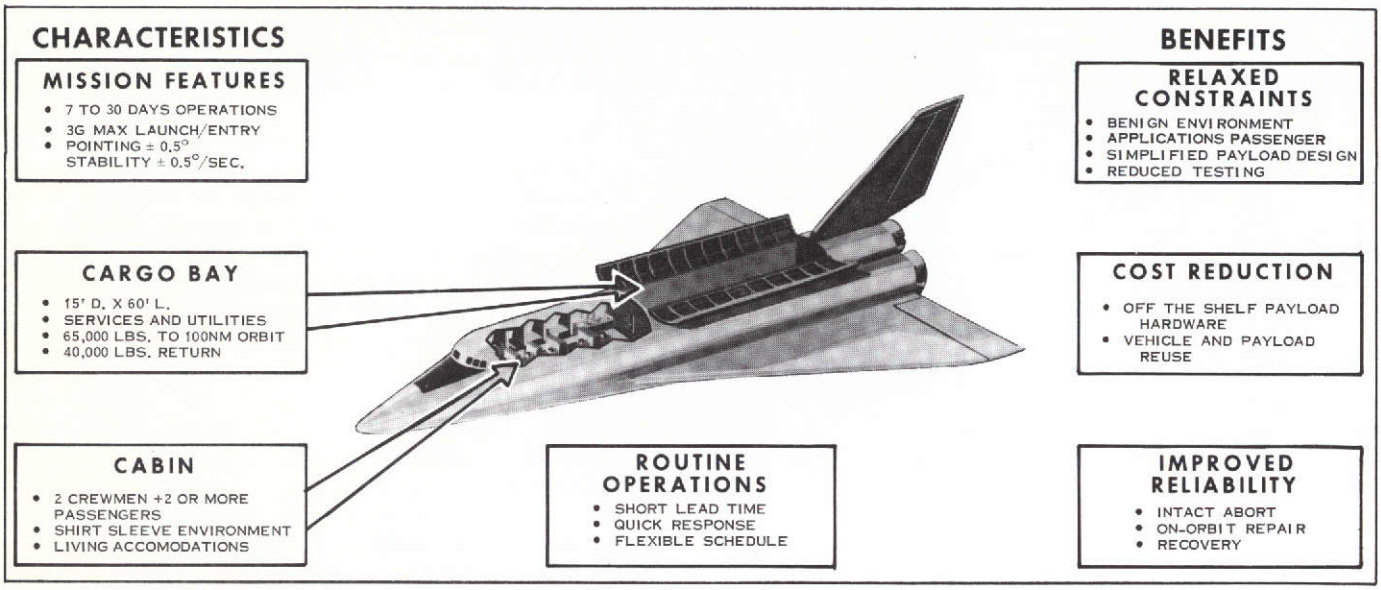

Figure 14. Space Shuttle

Task 3.0, Desired Time Phasing. Task 3 has assembled the preliminary timing information into an integrated schedule of when required knowledge and capabilities would be available for all identified products, processes, and services of value. Since there was no approved data for space program plans, there has been no "shaping" of the schedule, which occurs when attempts are made to fit "required" tasks into "available" slots.

Task 4.0, Commonality Analysis. Task 4 established the commonalities among the requirements for the knowledge, capabilities, timing and experiments/activities of Tasks 2 and 3. Commonality analysis for this Study, we learned, suffers from a key circumstance, Figure 15.

CIRCUMSTANCE	B.U.S. SOLUTION	RECOMMENDED ADDITIONAL SOLUTIONS
ZERO "G" IS MOST COMMON REQUIRED CONDITION	10_g^{-4} - 10_g^{-10} IS ZERO "G"	IN-DEPTH ANALYSIS TO DETERMINE SENSITIVITY OF PRODUCT, PROCESS, OR SERVICE TO "SMALL" G
SIMILAR PROBLEM WITH OTHER CONDITIONS	PRELIMINARY DEFINITION IS GOOD DESIGN CAN PROVIDE THE NOMINAL CONDITIONS	AS ABOVE
ISOLATION FROM VIBRATION		
HARD VACUUM		
LOW CONTAMINATION		
ETC.		

Figure 15. Lessons Learned in Performing Task 4.0

The level of analysis in this Study for specific requirements may not uncover differences in the acceptable tolerances on such generic requirements as zero "g", minimal vibration, etc. Such tolerance differences among the requirements for various experiments, tests, or processes may, however, negate a presumed commonality. Eventually, in-depth analyses will be required to settle such problems.

IV.4 CONCLUSIONS ON METHODOLOGY

After having exercised the preceding methodology, we are now in a position to draw some conclusions, Figure 16. Firstly, the method works. Prior to initiating the Study, it was generally agreed that, if we were able to uncover 5 or 6 good ideas, the Study would be a success. We have at least doubled those figures. Not only have we met the objectives of "Specific Problems" and "Specific Users" and "Specific Benefits", but we have come up with several ideas not previously documented.

• METHODOLOGY DEVELOPED DIALOG TECHNIQUE WORKS	• PRINCIPAL USER CONCERNS ROUTE FROM IDEA TO RETURN-ON-INVESTMENT (THE PAYOFF)
• 101 SPECIFIC IDEAS IDENTIFIED TO DATE 12 WORTHWHILE 37 MAY HAVE POTENTIAL 52 NO APPLICABILITY TO STUDY	PROPRIETARY PROTECTION RIGHTS-IN-DATA FUNDING NASA/USER ROLES FACILITIES DECISIONS

Figure 16. Conclusions – Methodology

Secondly, as we noted in preceding paragraphs, we have learned some valuable lessons – some utilized to modify the Study, others recommended for possible future consideration. We have also learned that more complete benefits analysis could be, and likely should be, performed.

It has become obvious that substantial commitments by potential Users will require more information for them, and longer association with them, to promote their confidence in pertinent space activities. A Business Planning Study would be a major step in that direction.

V BASIC DATA GENERATED AND SIGNIFICANT RESULTS

The interfaces with User organizations and Key Individuals within and outside GE were as extensive as planned, Figure 17. From dialogues carried on at such meetings, we were able to elicit 120 ideas of possible interest on this Study. Nineteen of the ideas did not evolve beyond initial discussions. As the Study progressed, many of the remaining ideas were eliminated through dialogues and analyses which disclosed their lack of specificity, mismatch with study constraints, overlap with other ideas, etc., so that, eventually, some 12 ideas continued to appear fruitful.

USER ORGANIZATIONS		KEY INDIVIDUALS	
GE	42		170
AEROSPACE GROUP	7	14	
OUTSIDE AEROSPACE	35	156	
OUTSIDE GE	49		233
TOTAL	91		403

Figure 17. User/Key Individual Meetings During Phase I

From those ideas which survived the analyses and evaluations carried out under the previously discussed tasks, we have drawn some key conclusions, Figure 18. While most ideas are based, as in earlier efforts, on the unique space property of zero "g", the advantage of isolation from the terrestrial environment has given rise to several worthwhile ideas.

APPLICATIONS

- ZERO G REMAINS MOST PROMISING SPACE "PROPERTY". REQUIRED FOR:
  - LEVITATION MELTING - EUTECTIC TURBINE BUCKETS, X-RAY TUBE TARGETS, AMORPHOUS OXIDES
  - CRYSTAL GROWTH - ELECTRONIC COMPONENT SUBSTRATES, SINGLE CRYSTAL TURBINE BUCKETS, SILICON POWER RECTIFIERS, GERMANIUM DETECTORS, GARNET FILM BUBBLE MEMORIES
  - SEPARATION OF PARTICLES - ELECTROPHORESIS FOR VACCINES, VIRUSES, BLOOD FRACTIONS, ISOENZYMES, ETC.
    - OTHER SMALL FORCES FOR SUCH AS RADIOISOTOPE SEPARATION
  - MEASUREMENTS - THERMAL CONDUCTIVITY OF FLUIDS
- ISOLATION FROM TERRESTRIAL ENVIRONMENT IS A DEVELOPING AREA - NEEDS INVESTIGATION. REQUIRED FOR:
  - VIBRATION, NOISE ISOLATION - IMPRINTING HIGH FREQUENCY CIRCUITRY, TESTING OF FRACTIONAL HORSEPOWER MOTORS
  - OTHER ISOLATION - UTILIZATION OF BIORHYTHMS
- NO IDENTIFIED USES FOR VERY HARD VACUUM*, TOTAL SOLAR SPECTRUM, SPACE RADIATION, PARTIAL OR INTERMITTENT G, UNLIMITED VOLUME AND DIMENSIONS, LAUNCH AND/OR REENTRY CONDITIONS
  *SECONDARY REQUIREMENT IN SOME CASES

BENEFITS

- ECONOMIC - EXTREMELY CONSERVATIVE ESTIMATES INDICATE ORDER OF BILLION $/YEAR GROSS DIRECT BENEFITS
- OTHER - MEDICAL (THERAPEUTIC, DIAGNOSTIC), PUBLIC LEVEL OF HEALTH HUMAN PERFORMANCE. ENVIRONMENT, MILITARY GAINS INDICATED BUT HARDER TO PIN DOWN. MORE STUDY REQUIRED

Figure 18. Conclusions – Data

In all, the major result of analyzing the 12 worthwhile ideas has been the identification of specific economic benefits amounting to over a billion dollars per year and the potential for thousands of lives saved per year, based on successful solutions to identified problems. The following paragraphs provide details on the ideas and associated benefits.

V.1 IDEAS SUPPORTED BY THE STUDY

The twelve ideas tabulated in Figure 19 are those for which the Study effort has been able to derive data responsive to the prescribed tasks and constraints. While most of the ideas reflect specific products (i.e., No. 1, Imprinting High Frequency Circuitry; No. 6, Gas Turbine Buckets; No. 30, Tungsten X-ray Targets; No. 42, Purer Radioisotopes; No. 46, Large Silicon Crystals; No. 59, Magnetic Bubble Memory Crystals; No. 60, Amorphous Oxides), there is one idea for a process, No. 3, Particle Manipulation; and three for services, No. 5, Vibration Testing; No. 84, Heat Transfer Data; and No. 96, Utilization of Biorhythms. In addition, No. 89, Separation of Isoenzymes, may provide products, a process and services.

Summary of Potential Benefits. Figure 20 summarizes estimates of the potential benefits accruing to various Users should space processing prove capable of solving the specific problems inhibiting the development or production of the items listed above. In all estimates, particular effort was exerted to assure conservatism in assumptions, calculations and analyses of benefits. As mentioned earlier, not all Users in the complete hierarchy involved in each idea could be analyzed, since the chain of Users can be quite extensive in some cases, and the study effort was limited. However, representative cases (Single Crystal and Eutectic Turbine Buckets, Idea No. 6; High Purity Tungsten X-ray Targets, Idea No. 30) show typical benefits at a number of levels.

Particle manipulation by small forces, Idea No. 3, is treated somewhat differently than others, since it is essentially a process, which has yet to find a credible User. While no economic or social benefits have been identified, the technical potential of emplacing or removing micro-sized particles in a variety of media by means of forces generated by light, sound, radio frequency waves, particulate radiation, etc. looks promising. Such forces, normally masked by the gravity force on earth, provide the prospective User with a "Tool Box" of particle manipulators that can be utilized in zero "g".

Vibration testing of small motors, Idea No. 5 exhibits the value of "leverage." While the better design and fabrication data potentially obtainable from vibration testing of prototype fractional horsepower electric motors in space may save only pennies per motor, the enormous quantity of motors produced per year may accrue as much as $38 million per year in benefits. Space processed turbine buckets, Idea No. 6, is projected to provide benefits to an extensive hierarchy of Users, the aircraft engine manufacturer ($31 to 36 million per year), the airlines $111 to 324 million per year), the public ($141 million per year) as well as pollution benefits.

Tungsten x-ray targets, Idea No. 30, is typical of products for which benefits may accrue through the utilization of levitation melting and subsequent supercooling. The idea demonstrates the potential of high value materials which are needed in relatively small quantities for specialized applications. Even

NO.	SUBJECTS	USERS/KEY INDIVIDUALS	GOALS	OBJECTIVES	ISSUES, NEEDS, AND PROBLEM AREAS
1	IMPRINTING CURCUITRY ON CRYSTAL WAFERS FOR SURFACE ACOUSTIC WAVE ELECTRONICS	GE/S. TEHON, S. WANUGA	PRINTED CIRCUITRY TO OPERATE AT >30 GIGAHERTZ	PRECISE IMPRINTING VIA ELECTRONIC BEAM	ELIMINATION OF VIBRATION FROM IMPRINTING SYSTEM
3	PARTICLE MANIPULATION BY SMALL FORCES	GE/H. SUMMERHAYES	MANIPULATION OF PARTICLES IN A MEDIUM BY SMALL FORCES	UTILIZATION OF SMALL FORCES FOR SEPARATION, REMOVAL, EMPLACEMENTS, ETC. OF PARTICLES	ELIMINATION OF GRAVITY MASKING EFFECT
5	VIBRATION TESTING OF SMALL MOTORS	GE/F. PETERS H. FRITZSCHE, R. MACGREGOR	HIGH RELIABILITY, LONG LIFE ELECTRIC MOTORS	IDENTIFICATION AND MEASUREMENT OF VIBRATION PATTERNS	IMPROVEMENT OF PRESENT 4 CPS LIMIT, ISOLATION FROM SONIC AND MAGNETIC FIELDS
6	SINGLE CRYSTAL AND EUTECTIC HIGH TEMPERATURE TURBINE BUCKETS	GE/L. JAHNKE, W. CHANG L. TARSHIS	GAS TURBINE BUCKETS CAPABLE OF 1650^{0}C OPERATION	SINGLE CRYSTAL OF SELECTED SUPERALLOYS AND EUTECTICS WITHOUT ANOMALIES	CERTAIN SUPERALLOYS NOT AMENABLE TO CASTING; PRESENT CRYSTALS SMALL AND CONTAIN DISLOCATIONS; EUTECTICS CONTAIN DISLOCATIONS, ETC.
30	HIGH PURITY TUNGSTEN X-RAY TARGETS	GE/W. LOVE	LONGER LIFE TARGETS	PURER TUNGSTEN	CONTAMINATION OF MELT BY . CRUCIBLE.
42	PRECISE SEPARATION OF RADIOISOTOPES	GE/F. CHANNON, P. BROWN	SEPARATION OF PLUTONIUM ISOTOPES	PRECISE SEPARATION OF ISOTOPES IN CLOSE PROXIMITY IN PERIODIC TABLE	HIGH SPECIFICITY TECHNIQUE
46	SILICON CRYSTAL GROWTH	GE/R. HALL	LARGE UNIFORM SILICON CRYSTALS FOR HIGH VOLTAGE DC POWER RECTIFICATION	6 TO 8 INCH CRYSTALS WITH UNIFORM STRUCTURE AND HOMOGENEITY	CONVECTION DURING CRYSTAL GROWTH
59	EPITAXIAL GROWTH OF MAGNETIC BUBBLE MEMORY CRYSTALS	CORNING/G. SMITH F. FEHLNER	SINGLE CRYSTAL GARNET FILMS	BETTER THAN 1% UNIFORMITY IN THICKNESS AND MAGNETIC PROPERTIES	CONVECTION, LOSS OF SUPERSATURATION
60	AMORPHOUS GLASSES AND REFRACTORIES	CORNING/G. SMITH, R. WASSON, J. MACDOWELL	HIGH STRENGTH GLASSES AND REFRACTORIES	AVOIDANCE OF CRYSTALLIZATION BY SUPERCOOLING, ZERO CONTAMINANTS	CRYSTALLIZATION DUE TO INCLUSIONS, CONVECTION
84	BASIC HEAT TRANSFER DATA	NATIONAL BUREAU OF STANDARDS/ PURDUE U. P. LILEY	ACCURATE THERMAL CONDUCTIVITY IN LIQUIDS	BETTER THAN 2 - 5% ACCURACY BY MINIMIZING CONVECTION	CONVECTION DURING MEASUREMENTS
89	SEPARATION IF ISOENZYMES	POLYSCIENCES INC./ B. HALPERN, K. AKKAPEDDI	USABLE QUANTITIES OF ISOENZYMES FOR MEDICAL THERAPY, ANALYSIS	SEPARATION OF ISOENZYMES BY GENTLE TECHNIQUES	DENATURATION OF ISOENZYMES BY SEPARATION UNDER G LOADING
96	UTILIZATION OF BIORHYTHMS	U. OF MINNESOTA/ NAT'L INSTITUTES OF HEALTH/ F. HALBERG F. BARTTER	USE OF BIORHYTHMS IN MEDICAL THERAPY AND PERFORMANCE IMPROVEMENT	KNOWLEDGE OF, AND CHANGING BIORHYTHMS	TERRESTRIAL INFLUENCES

Figure 19. Continuing Identified Ideas

with conservative assumptions, such tungsten x-ray targets yield composite yearly benefits of $19 million per year.

Crystal growth in space appears to offer great potential for many applications. Two examples are given here. The large silicon crystals of Idea No. 46 appear to offer benefits in both medical and power rectification applications. While numerical benefits of the medical advantages of soft tissue viewing have been difficult to ascertain, the benefits in the power area, based on the possibility of eventual megavolt dc power transmission, reflect considerable economic value ($50 to $100 million per year).

The future for the magnetic "bubble" memories of Idea No. 59 appears to be bright. Since it appears that the rigid magnetic and thickness tolerances (+1%) required of single crystal garnet films for such application can likely only be met by space processing, the $50 million dollar savings benefit indicated focuses considerable interest on this application.

While thermal conductivity of liquids, Idea No. 84, is virtually a "research" idea, the NBS is the focal point of many national and international commercial organizations who require such data. Although the NBS may not benefit directly from this idea, subsequent tiers of Users undoubtedly will.

Time-Phasing of Experiments/Activities to Develop/Produce Products, Processes, Services of the Continuing Ideas. One of the required Study results is a preliminary integrated timeline of development steps which would lead to the production or operation of the products, processes, and services listed earlier.

Since the majority of Users indicated early need for their identified ideas, the constraint on development schedules became the availability of resources and facilities, rather than required output dates. Since such availabilities are not yet established, the resulting schedule must be regarded as hypothetical, although the technical rationale for the progression of steps is logical.

IDEA NO.	TITLE	POTENTIAL DIRECT BENEFITS	POTENTIAL INDIRECT BENEFITS	REMARKS
1	IMPRINTING CIRCUITRY ON CRYSTALS FOR *ACOUSTIC* WAVE ELECTRONICS	AIRPORT AND AVOIDANCE RADAR - $3x10^6/YR POTENTIAL COMMUNICATIONS MKT - $100x10^6/YR MILITARY	INCREASE OVERSEAS MARKET ELECTRONICS COMPONENTS IMPROVE BALANCE/ PAYMENTS	DEFENSE NEEDS URGENT 90% REJECTS NOW
3	PARTICLE MANIPULATION BY SMALL FORCES	POSSIBLE NEW MANUFACTURING TECHNIQUES ACTUAL BENEFITS AWAIT IDENTIFICATION OF USERS		POSSIBLE APPLICATIONS: SEPARATIONS ISOTOPES GRADED SIZES PARTICLES BIOLOGICALS DISPERSION CONTROL OPTICAL FILTERS PHOTOTROPIC GLASSES OPTICAL WEDGES COMPOSITE MATERIALS
5	VIBRATION TESTING OF SMALL MOTORS	FUNDAMENTAL ENGINEERING DATA TO IMPROVE DESIGNS; THUS POSSIBLY: • 1¢ TO 8¢/MOTOR MATL SAVED BY BETTER DESIGN - $1.25 TO $10x10^6/YR • QUIETER, 25% LONGER LIFE MOTORS COULD ADD $37x10^6 SALES/YR LONGER LIFE - SAVE PUBLIC $56 x 10^6	QUIETER OPERATION, LESS VIBRATION, RELIABILITY ADD TO HUMAN COMFORT, HEALTH AND CUSTOMER SATISFACTION REDUCE MANUFACTURING COSTS INCREASE PRODUCER MARKET SHARE	125 MILLION MOTORS MADE PER YR IN U.S. SPACE VIB. TEST FAC. APPLICABLE TO MANY INDUSTRIES POSSIBLE IMPROVEMENT IN STATE-OF-THE-ART IN VIB. AND NOISE CONTROL
6	SINGLE CRYSTAL & EUTECTIC AIRCRAFT TURBINE BUCKETS	SAVE BUCKET REPLACE - $4.5x10^6/YR AND LESS FUEL BURNED - $32x10^6/YR OR INCREASE THRUST P/L REVENUE - $288 x 10^6/YR OR DECREASE WEIGHT INCREASE P/L - 75 x 10^6/YR AND SAVE MATERIAL DEV. COSTS - $11x10^6 SAVE ENGINE DEV. AND QUAL. - $20 TO $25 x 10^6 REDUCE FARES - SAVE PUBLIC $19 x 10^6 BENEFITS TO OTHER JET USERS: PETROLEUM, MARINE, ELECTRIC UTILITIES, ETC.	1.5 x 10^6 M^3 LESS FUEL BURNED POLLUTION REDUCED 7.8 x 10^6 KG/YR., OIL IMPORTS REDUCED 47.6 x 10^6 BARRELS/YR BAL/PAYMENTS REDUCED $122 x 10^6/YR, OIL CONSERVATION INCREASE U.S. GNP IMPROVE PUBLIC SAFETY IMPROVE NATIONAL DEFENSE DECREASE DOD BUDGET INCREASE PUBLIC TRAVEL	NO_X MIGHT INCREASE. CONSERVATIVE ESTIMATES FOR AIRLINE BENEFITS: 50% ADOPTION 50% LOAD FACTOR COST TO ACCOMPLISH NOT INCLUDED
	NOTE: THESE BENEFITS POSSIBLE ALSO FROM ANY MATERIAL WITH 150° C TEMP IMPROVEMENT i.e., NEW ALLOYS, CERAMICS, REFRACTORIES, FIBER REINFORCED COMPOSITES, SUPERCOOLED GRAIN STRUCTURES, ETC.			
30	HIGH PURITY TUNGSTEN X-RAY TARGETS	SAVE RHENIUM ADDITIVE - $975K/YR AND SAVE REPLACE OF FAILURES - $125K/YR AND LONGER LIFE SAVES HOSPITALS AND LABS - $17.9 x 10^6/YR	DECREASE COST OF X-RAY TUBES RELIABLE AND CONVENIENT LESS INVESTED LESS X-RAY RE-TAKES SAVE LABOR SAVE MATERIALS LESS EXPOSURE SAFER	ASSUMED 50% USAGE 50% TUBE LIFE INCREASE
42	PRECISE SEPARATION OF ISOTOPES	PACEMAKER POWER SUPPLIES $5 x 10^6 - $15 x 10^6/YR LESS GAMMA CONTAMINATION	CHEAPER AVAILABILITY - MORE USE SAFER MEDICAL APPLICATIONS QUANTITY NEED FOR POWER GENERATION NOW	HIGH PURITY Pu^{238} COSTS $1 x 10^6 TO $3 x 10^6 KG - POSSIBLE ORDER OF MAGNITUDE COST REDUCTION MEDICAL APPLICATIONS: ARTIFICIAL HEART, HEART PACEMAKERS NATIONAL DEFENSE USES MORE EFFICIENT SEPARATION OF OTHER ISOTOPES
46	SILICON CRYSTAL GROWTH FOR POWER AND MEDICAL APPLICATIONS	BETTER RADIOGRAPHY PICTURES FOR MEDICAL USES NEEDED FOR ELECT POWER GROWTH, 91 x 10^3 TO 182 x 10^3 KG/YR REQUIRED BY 1990, VALUE EST. $50 TO $100 x 10^6/YR	BETTER LOCATION AND IMAGES OF DISEASED TISSUE UNDERGROUND HVDC TRANSMISSION LESS LAND USE, CHEAPER URBAN INSTALLATION, LESS POWER LOSS LARGE CRYSTALS REQUIRE LESS PERIPHERAL EQUIPMENT EXPORTS INCREASED; BAL/PAYMENT IMPROVED PUBLIC SAFETY; EMI REDUCED	MORE UNIFORM CRYSTALS GIVE SHARPER LOCATION ASSUMED: 50% CRYSTALS OF REQUIRED (1990) LARGE SIZE 100 TO 150 MM DIAM CRYSTALS WITH FEW IMPERFECTIONS POWER SYSTEM CHEAPER TO BUILD AND OPERATE
59	EPITAXIAL GROWTH OF MAGNETIC BUBBLE MEMORY GARNET CRYSTALS	53,000 KG @ $7K/LB IN 1980, SAVE $50x10^6/YR BY SPACE PROCESSING	BETTER COMPUTER MEMORY UNITS, SMALLER, CHEAPER, HIGHER MEMORY CAPACITY APPLICABLE USE IN DISPLAYS	EST. MARKET IN 1980 - $380x10^6 LARGER CHIPS POSSIBLE IN SPACE, LOWER COST/BIT, MORE UNIFORM CHARACTERISTICS EXPECTED TO DOMINATE MARKET BY 1980 LESS SPOILAGE IN PRODUCTION
	NOTE: BENEFIT DATA FROM NASA/MSFC CONTRACT NAS8-27942, "ECONOMETRIC ANALYSIS OF CRYSTAL GROWTH IN SPACE" BY GE			
60	AMORPHOUS OXIDES	NEW GLASSES WITH SUPERIOR CHARACTERISTICS: *IR TRANSPARENCY, HIGH STRENGTH, PURITY & MELTING POINT, *OPTICAL QUALITIES, THERMAL SHOCK RESIST., REINFORCING FIBERS SHARE OF SCIENCE AND TECHNOLOGY GLASS MKT $90 x 10^6/YEAR *SHARE OF OPTICAL INSTRUMENTS AND LENS MARKET $10 x 10^6/YEAR	NATIONAL DEFENSE APPLICATION	COMMUNICATION BY WIDE-BAND LIGHT BEAMS AND FIBER OPTICS REINFORCING FIBERS *AND INSULATION* APPLICATION LASER AND HIGH INTENSITY LAMP GLASS APPLICATION 5 TO 10 MICRON INFRARED TRANSPARENCY MAJOR IMPROVEMENT IN GLASSES TECHNOLOGY MAY APPLY TO OBTAIN AMORPHOUS METALS, NITRIDES, ETC.
84	THERMAL CONDUCTIVITY OF LIQUIDS	REDUCE ERRORS (UP TO 25%) IN THERMAL CONDUCTIVITY MEASUREMENT OF LIQUIDS REDUCE MATERIAL COSTS IN DESIGN OF HEATERS, HEAT EXCHANGERS, AND OTHER INDUSTRIAL EQUIPMENT	REDUCE DESIGN AND TEST EFFORT IMPROVE OPER. CHARACTERISTICS AND REDUCE OPERATION COSTS OF THERMAL HEATERS AND INSULATION	NATIONAL BUREAU OF STANDARDS PROVIDES THERMAL DATA ON MATERIALS ALL OVER THE WORLD DATA ALSO APPLIED TO METEOROLOGY, LIMNOLOGY, OCEANOLOGY, ETC.
89	SEPARATION OF ISOENZYMES	SAVE LIVES BY EARLY DETECTION AND TREATMENT: 10% OF BREAST CANCERS ~2,000; 10% OF CERVIX CANCERS ~1,000 PUBLIC HEALTH IMPROVED IMPROVE MEDICAL DIAGNOSIS AND THERAPY SEPARATION OF OTHER BIOLOGICAL MACROMOLECULES: HISTONES, RIBOSOMES, INTERFERONS	AID GENETIC, ONTOGENIC, PHYLOGENIC STUDIES	PROCESS LIKELY BETTER IN SPACE
96	UTILIZATION OF BIORHYTHMS	FUNDAMENTAL KNOWLEDGE OF GEOLUNAR EFFECTS ON BIORHYTHMS 10% IMPROVEMENT IN PERFORMANCE OF ROTATING SHIFTS WOULD ADD 1.5% IN TOTAL SHIFT OUTPUTS BETTER MEDICAL THERAPY IMPROVE FLIGHT CREW PERFORMANCE; $100K SAVINGS FOR STEWARDESSES ALONE AGRICULTURE AND ANIMAL USES TO INCREASE OUTPUT	BETTER DEFINITION OF "HEALTH" MEASUREMENT ON ONE CARDIAC PATIENT IN ORBIT MAY APPLY TO MANY ON EARTH IMPROVE DRUG TOXICITY MEASURES	CURRENTLY IMPRACTICAL FDA DRUG TOXICITY TECHNOLOGY (LETHAL DOSE - 50%) IS INADEQUATE

Figure 20. Benefits Summary

Figure 21 indicates the program phase versus time for each of the ideas, based on the estimated duration of each phase, including preparatory effort, accomplishment of the tasks involved, reconciliation of the results, and typical administrative activities. It must be noted that the schedule is given only as an example, and that considerably more data is required before specific planning can begin.

V.2 IDEAS RECOMMENDED FOR FUTURE CONSIDERATION

Figure 22 provides an overview of ideas not carried completely through the study tasks, but which the study team feels have sufficient potential merit to warrant future study.

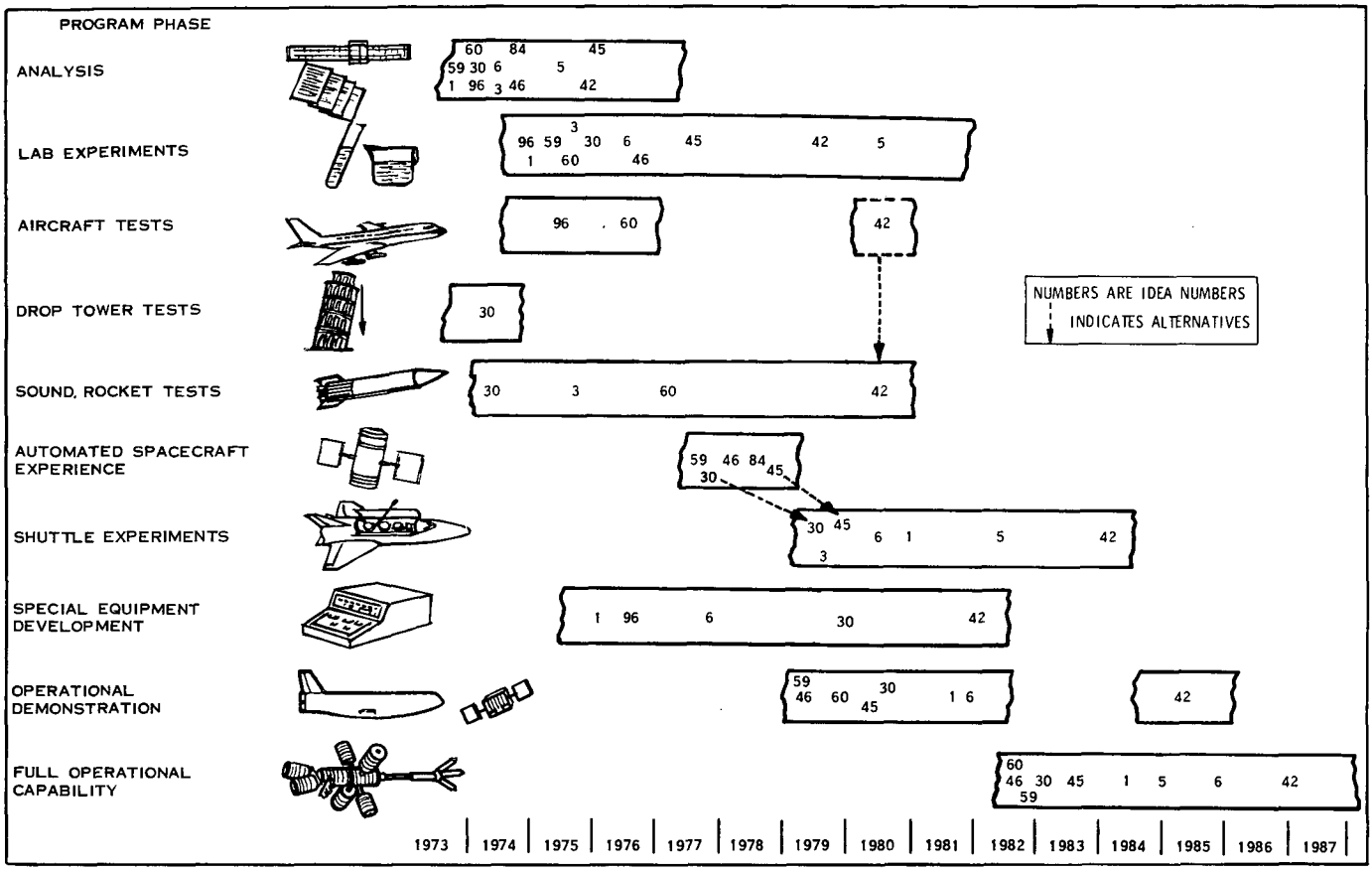

Figure 21. Integrated Time Phasing of Space Experiments/Activities

NO.	SUBJECT	GOALS/OBJECTIVES	ISSUES, NEEDS, PROBLEM AREAS	WHY NOT CONTINUING
11	EUTECTICS FOR COLD CATHODES	PRECISE MICROPROJECTIONS TO ENABLE WELL-DISTRIBUTED ELECTRON EMISSION	LOADINGS DURING SOLIDIFICATION	NO SPECIFIC USER
14	HIGHER PURITY FIBER OPTICS	MINIMIZE ATTENUATION VIA INCREASED PURITY	CONTAMINATION OF MELT	NO SPECIFIC USER
23	FLUIDIC WAFER STACKS	HIGHER DENSITY, STRENGTH WAFERS, SPECIAL COMPOSITES	VOIDS RESULTING FROM POWDER METALLURGY, NON-UNIFORM COMPOSITES	LACK OF TIME
38	DISPOSAL OF RADIOACTIVE WASTES	SAFE, NON-POLLUTING DISPOSAL	LONG HALF LIVES, PUBLIC APPREHENSION	OUTSIDE STUDY CONSTRAINT
45	LARGE GERMANIUM CRYSTALS	30 X 30 CM CRYSTALS FOR GAMMA RAY CAMERA	DISTORTION, LOW RESOLUTION FROM SMALL CRYSTAL MATRICES, 30 X 30 CM CRYSTALS NOT OBTAINABLE IN ONE "G"	LACK OF TIME
57	BLOOD ANALYSIS SERVICE	UNIQUE ANALYSES, SERVICE TO DOCTORS, HOSPITALS	SPECIFICITY OF ANALYSIS	NO SPECIFIC USER
90	IMPROVED BATTERIES, CAPACITORS	IMPROVED MEMBRANES, SOLID ELECTROLYTES	THINNER MEMBRANES, ELECTROLYTE PARTICLE SIZE	NO SPECIFIC REQUIREMENTS, LACK OF TIME
92	OPTICAL FILTERS	PRECISE GRADATION, DENSITY CONTROL	PRECISE PARTICLE IMPLANTATION	NO SPECIFIC USER
95	CORROSION RESISTANT ELECTRODES	ELECTRICALLY CONDUCTIVE REFRACTORY ELECTRODES VIA SUPERCOOLING AND RADIATION	LOW CONDUCTIVITY OF PRESENT FORMS; LIMITED COOLING CAPABILITY	LACK OF TIME
97	CARBON BASED FILAMENTS	HIGHER STRENGTH FILAMENTS FOR REINFORCING PLASTICS	REMOVAL OF ADDITIONAL HC_L, N_2. LARGE VOLUMES OF VACUUM	NO SPECIFIC REQUIREMENTS, LACK OF TIME
98	NEW ANTIBIOTICS	USEFUL MUTATIONS OF ANTIBIOTIC-PRODUCING ORGANISMS THROUGH SYNERGISTIC EFFECTS OF RADIATION AND ZERO G	RADIATION ALONE MAY BE INSUFFICIENT	LACK OF TIME
101	ENHANCED SOLAR INSOLATION	DISSIPATE FOG, DRY FLOODED AREAS	MOBILE, LARGE REFLECTOR OR LENS	NO SPECIFIC REQUIREMENTS, LACK OF TIME

Figure 22. Identified Ideas Recommended for Future Consideration

Those items noted with "lack of time" surfaced late in the Study and reflect the "gestation" period required by many non-aerospace companies to absorb the information we provided as "seeds" for their consideration. Unfortunately, there was insufficient time to both investigate these ideas and complete the study milestones.

V.3 OTHER IDEAS

The preceding pages have accounted for 24 of the 120 ideas noted during the Phase I Study. Due to page limitations on this volume of the Final Report, review of the remaining ideas, on which effort was terminated for documented reasons, will be discussed in Volume II. Figure 23, however, lists the disposition of all of the 101 applicable ideas generated during the Phase I Study.

IDEA NO.	IDEA	DISPOSITION
1	IMPRINTING CIRCUITRY FOR SURFACE ACOUSTIC WAVE ELECTRONICS	COMPLETE - REPORT ISSUED BY GE-ELEC. LAB
2	LEAD WIRE AND FILAMENT MATERIALS FOR HIGH INTENSITY LAMPS	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
3	PARTICLE MANIPULATION BY SMALL FORCES	COMPLETE - REPORT ISSUED BY GE-CR&D
4	AFFINITY CHROMATOGRAPHY	DISCONTINUED - SPECIFIC USER NOT IDENTIFIABLE
5	VIBRATION TESTING FOR FRACTIONAL HP MOTORS	COMPLETE - REPORT ISSUED BY GE-APPL. COMP. LAB
6	SINGLE CRYSTAL HIGH TEMPERATURE TURBINE BUCKETS	COMPLETE - REPORTS ISSUED BY GE-AEG, EASTERN AIRLINES, DR. CHUNG
7	MAGNETRON TUBE MANUFACTURE	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
8	SPECIALTY GLASS	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
9	MICROSPHERE SPECTROSCOPE AND SPECTROSCOPY	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
10	SEMICONDUCTOR PROCESSING	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
11	GROWTH OF EUTECTICS FOR COLD CATHODES	DISCONTINUED - RECOMMEND FUTURE CONSIDERATION
12	DEVELOPMENT OF HIGH TEMP. HIGH STRENGTH ALLOYS AND EUTECTICS	DISCONTINUED - PARTIALLY INCORPORATED IN NO. 6
13	UNIFORM MIXING OF LEAD TELLURIDE	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
14	HIGHER PURITY FIBER OPTICS MATERIALS	DISCONTINUED - RECOMMEND FUTURE CONSIDERATION
15	PLATING OF POROUS STRUCTURES	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
16	COATING OF OPTICAL REFLECTORS	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
17	HIGHER PURITY THERMOCOUPLE MATERIALS AND BONDS	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
18	SINGLE CRYSTAL LAMP FILAMENTS	DISCARDED - NOT FEASIBLE
19	IMPROVED UNIFORMITY IN POWDER METALLURGY	DISCARDED - MINOR APPARENT ADVANTAGE TO SPACE OPS
20	SEMICONDUCTOR SOLDERING TECHNIQUES	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
21	COATING IMPLANTABLE MEDICAL SENSORS	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
22	IMPROVED PROPERTIES IN TRANSFORMER MATERIALS	DISCARDED - NO MATCH BETWEEN PROBLEMS AND SPACE PROPERTIES
23	IMPROVED BONDING OF WAFERS IN FLUIDIC STACK	DISCONTINUED - RECOMMEND FUTURE CONSIDERATION
24	ULTRA UNIFORM GRAIN IN PHOTOGRAPHIC EMULSIONS	DISCONTINUED - SPECIFIC USER NOT IDENTIFIABLE
25	IMPROVED ENAMEL FILM ON COPPER WIRE	DISCONTINUED - SPECIFIC USER NOT IDENTIFIABLE
26	IMPROVED NUCLIPORE FILTER	DISCONTINUED - SPECIFIC USER NOT IDENTIFIABLE
27	PROSTHETIC MATERIAL FOR BONE GROWTH	DISCONTINUED - NO SPECIFIC USER REQUIREMENT IDENTIFIED
28	IMPROVED MATERIALS FOR GAS TURB. MECHANISMS AND SERVOS	DISCARDED - NO MATCH BETWEEN PROBLEMS AND SPACE PROPERTIES
29	THIN FILMS FOR DIALYSIS AND/OR WATER PURIFICATION	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
30	HIGH PURITY TUNGSTEN TARGET FOR X-RAY TUBES	COMPLETE - REPORT ISSUED BY GE-MED. SYS. DEPT
31	SILICON STEEL WITH BETTER ELECTRICAL CHARACTERISTICS	DISCARDED - NO MATCH BETWEEN PROBLEMS AND SPACE PROPERTIES
32	DEVELOPMENT AID IN PHONOCARDIOLOGY	DISCONTINUED - APPEARS RESEARCH
33	PROTECTIVE COATINGS ON BEARING ROLLERS	DISCARDED - NO MATCH BETWEEN PROBLEMS AND SPACE PROPERTIES
34	HIGH QUALITY THERMOSTATIC CONTROLS	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
35	IMPROVED DAIRY PRODUCTS	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
36	BONE GROWTH IN ZERO "G" ENVIRONMENT	DISCONTINUED - APPEARS RESEARCH
37	ACCELERATED HOUSING MATERIALS EXPOSURE TESTING	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
38	SAFE DISPOSAL OF RADIOACTIVE WASTES	DISCONTINUED - NOTED TO COR, OUTSIDE STUDY CONSTRAINTS
39	ZIRCONIUM CLADDING OF NUCLEAR FUEL ELEMENTS	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
40	SPONGE "GETTER" ALLOYS FOR NUCLEAR GAS PRODUCTS	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
41	EVACUATION AND SEALING OF IR TUBES	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
42	PRECISE SEPARATION OF RADIOISOTOPES	COMPLETE - REPORT ISSUED BY GE-NUC. SYS PROG.
43	CAVITATION AND SURFACE WETTING PHENOMENA	DISCONTINUED - APPEARS RESEARCH
44	WELDING OF SPECIAL MATERIALS; e.g., COPPER-ALUMINUM	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
45	LARGE Ge CRYSTALS FOR X-RAY CAMERA	DISCONTINUED - RECOMMEND FUTURE CONSIDERATION
46	LARGE Si CRYSTALS FOR POWER AND MEDICAL APPLICATIONS	COMPLETE - ANALYSIS REPORT AVAILABLE
47	FILAMENT STRUCTURES, METALLIC WHISKERS AND FIBERS	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
48	VIRAL INSECTICIDE MANUFACTURE	DISCONTINUED - COVERED IN RELATED STUDY
49	VACCINES, IMPROVED	DISCONTINUED - COVERED IN RELATED STUDY
50	LYOPHILIZATION (FREEZE DRYING)	DISCONTINUED - EARLIER GENERALIZED IDEA
51	UNIFORM DISPERSION OF PARTICLES	DISCONTINUED - EARLIER GENERALIZED IDEA
52	FIBER REINFORCED COMPOSITE MATERIALS	DISCONTINUED - EARLIER GENERALIZED IDEA
53	CEMENTED COMPOSITES	DISCONTINUED - EARLIER GENERALIZED IDEA
54	LIQUID DISPERSIONS - SLIP CASTING	DISCONTINUED - EARLIER GENERALIZED IDEA
55	FREE CASTING OF METALS IN ZERO "G" ENVIRONMENT	DISCONTINUED - EARLIER GENERALIZED IDEA
56	FINE GRAIN CASTING	DISCONTINUED - EARLIER GENERALIZED IDEA
57	BLOOD ANALYSIS SERVICE	DISCONTINUED - RECOMMEND FUTURE CONSIDERATION
58	MEMORY DEVICES BASED ON EUTECTIC STRUCTURES	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
59	EPITAXIAL CRYSTAL GROWTH OF GARNET FILMS FOR MAGNETIC BUBBLE MEMORY	COMPLETE - REPORTS ISSUED BY GE-CR&D AND CORNING
60	AMORPHOUS GLASSES AND REFRACTORIES	COMPLETE - REPORT ISSUED BY CORNING
61	FERROELECTRIC TRANSDUCERS	DISCONTINUED - RECOMMEND POSSIBLE FUTURE CONSIDERATION
62	PRECISION SHAPING OF MIRRORS	DISCARDED - NO MATCH BETWEEN PROBLEMS AND SPACE PROPERTIES
63	LEVITATION MELTING OF METAL	DISCONTINUED - EARLIER GENERALIZED IDEA
64	STRESS - FREE GLASS CASTINGS	DISCONTINUED - INCORPORATED IN IDEA NO. 60
65	SUPER THIN SAW BLADES FOR CRYSTALS	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
66	PARTICLE TRANSPORT IN VAN ALLEN BELT	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
67	X-RAY TUBE PHOSPHOR DEPOSITION	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
68	MUTATION AND GROWTH OF MICRO-ORGANISMS	DISCONTINUED - APPEARS RESEARCH
69	GLASS FIBERS IN LAMINANTS	DISCONTINUED - SPECIFIC USER NOT IDENTIFIABLE
70	SILICON IMPURITIES REMOVAL	DISCONTINUED - INCORPORATED IN IDEA NO. 46
71	GALLIUM-INDIUM-PHOSPHIDE CRYSTAL GROWTH	DISCONTINUED - COVERED IN RELATED STUDY
72	REMOVE BORON-OXIDE IMPURITIES	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
73	EMISSION SPECTROGRAPHY OF GLASS	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
74	FACILITY FOR PRECISE ALLOY FORMULATION AND ALLOY ANALYSIS	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
75	THERMOGRAPHIC AND NUCLEAR SCANNING	DISCARDED - NO MATCH BETWEEN PROBLEMS AND SPACE PROPERTIES
76	EDGE BONDING PLASTIC SHEET	DISCARDED - NO MATCH BETWEEN PROBLEMS AND SPACE PROPERTIES
77	INTERRUPTER ASSEMBLY	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
78	ALLOY PREPARATION - REMOVAL OF OXYGEN	DISCONTINUED - INCORPORATED INTO IDEA NO. 74
79	CROSSLINK OF POLYMERS BY RADIATION	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
80	CRYOGENIC SUPERCONDUCTIVITY FACILITY	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
81	IMPROVED MAGNETIC MATERIALS	DISCONTINUED - NO SPECIFIC USER REQUIREMENT IDENTIFIED
82	COPPER DEPOSITION ON SUBSTRATE	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
83	GLASS AND CERAMIC TO METAL SEALS	DISCARDED - NO APPARENT ADVANTAGE TO SPACE OPS
84	THERMAL CONDUCTIVITY OF LIQUIDS	COMPLETE - REPORT ISSUED BY GE-CR&D
85	ULTRA-FINE WIRE	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
86	MEDICAL TECHNIQUES	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
87	SMALL SPHERES - GROSS ATOMIZATION	DISCONTINUED - NO SPECIFIC USER REQUIREMENT
88	NUCLEAR REACTOR MATERIALS	DISCONTINUED - INCORPORATED IN IDEAS NOS. 39, 42
89	SEPARATION OF ISOENZYMES	COMPLETE - REPORT ISSUED BY POLYSCIENCES
90	IMPROVED BATTERIES AND CAPACITORS	DISCONTINUED - RECOMMEND FUTURE CONSIDERATION
91	CALIBRATION OF TEST EQUIPMENT	DISCONTINUED - SPECIFIC USER NOT IDENTIFIABLE
92	OPTICAL FILTERS - TECHNOLOGY	DISCONTINUED - RECOMMEND POSSIBLE FUTURE CONSIDERATION
93	CERAMICS AND REFRACTORY MATERIALS	DISCONTINUED - PARTIALLY INCORPORATED INTO IDEAS NOS. 8, 60
94	METAL PURIFICATION	DISCONTINUED - INCORPORATED IN SPECIFIC IDEAS
95	CORROSIVE RESISTANT ELECTRODES	DISCONTINUED - RECOMMEND FUTURE CONSIDERATION
96	UTILIZATION OF BIORHYTHMS	COMPLETE - REPORT ISSUED BY NIH AND U. OF MINN.
97	HIGH STRENGTH CARBON-BASED FILAMENTS FOR PLASTIC REINFORCEMENT	DISCONTINUED - RECOMMEND FUTURE CONSIDERATION
98	NEW ANTIBIOTICS	DISCONTINUED - RECOMMEND FUTURE CONSIDERATION
99	MASS SPECTROMETRY IN SPACE	DISCONTINUED - RECOMMEND FUTURE CONSIDERATION
100	HIGH PURITY RARE EARTHS	DISCONTINUED - RECOMMEND FUTURE CONSIDERATION
101	ENHANCED SOLAR INSOLATION	DISCONTINUED - NOTED TO COR, OUTSIDE STUDY CONSTRAINT

IN ADDITION, 19 IDEAS WERE MENTIONED IN PASSING BY VARIOUS INDIVIDUALS, BUT WERE NOT CONSIDERED BY THEM TO BE SUFFICIENT APPLICABILITY TO WARRANT FURTHER DISCUSSION. SUCH IDEAS INCLUDED SEVERAL ON INSTRUMENTATION AND SENSORS, OTHERS ON BASIC PHYSICAL AND CHEMICAL PHENOMENA, AND A FEW ON HIGH VALUE MATERIALS.

Figure 23. Disposition of Identified Specific Ideas

VI STUDY LIMITATIONS

The Phase I Study for Identification of Beneficial Uses of Space has been performed within the administrative and technical bounds defined by the contract for the Study, the direction from the NASA C.O.R., and the limited state-of-art in space processes extant in non-aerospace organizations. Thus, the final information documented for the Study is valid only for the conditions noted.

VI.1 LIMITATIONS OF A TECHNICAL NATURE

Categories of Technical Areas. As noted earlier, contract and NASA C.O.R. direction emphasized four main areas of interest in order to focus study effort:

1. Commercial Products
2. New Mechanical or Chemical Processes
3. Improved Medicines
4. New Medical Techniques or Equipment

The C.O.R. allowed liberal interpretation of these categories, and the exclusion of such areas as communications, earth surveys, etc. did not unduly restrict the acquisition of a large volume of information.

Depth of Analysis. A number of ideas identified during the Study involve phenomena, reactions, and interactions in the disciplines of thermodynamics, fluid dynamics, kinetics, etc. which should, eventually, be analyzed in depth to ascertain or verify the validity of key processes. At the direction of the C.O.R., with the intention of merely "Identifying" Beneficial Uses of Space, only brief analyses of selected ideas were carried out. The Study ideas, therefore, must be considered as conceptual, a baseline for later analytical and experimental investigation in depth.

VI.2 LIMITATIONS OF AN ADMINISTRATIVE NATURE

Restriction of Initial Effort. The intent of limiting initial subtasks to GE and companies with existing relationships was to delay outside contacts until we had developed our Study techniques, and, indeed, the intent was effective. The initial 3-month delay, however, and the "gestation" time of many non-aerospace organizations then resulted in late submittal of ideas. We accommodated some late results, but some ideas were left "for future consideration".

User Concerns. As the Study proceeded, it became apparent that some companies were more concerned with potential business relationships that could develop as a result of their involvement with "space" to produce commercial products than with the new technical capabilities offered. Figure 24 lists typical questions that reflect that concern.

What is sought, we have concluded, is not necessarily answers that are all favorable to commercial industry, but rather answers that allow evaluations and decisions to be made. The business community is realistic, and in making decisions to pursue new businesses, especially those that involve costly programs, it requires realistic estimates of the risks – not assurance of zero risk.

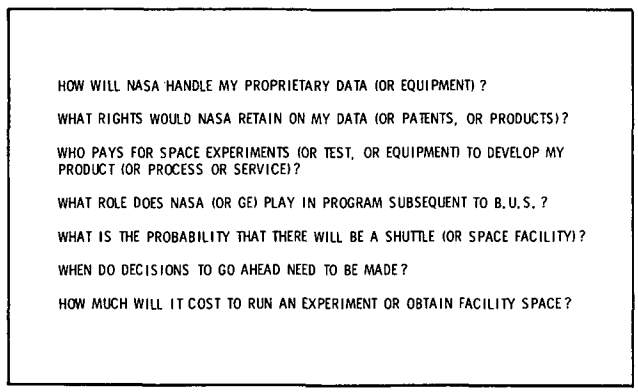

Figure 24. Typical Questions

While the Study Team did provide temporizing answers to some of these questions, it is felt that participation of some organizations was likely inhibited by trepidation over the business planning aspects represented by the questions.

VII IMPLICATIONS FOR RESEARCH

All of the Ideas generated during this phase of the Study must be viewed, in the light of the very cursory analyses possible within the limited time and funding of the Study, as technically speculative. The preliminary experimentation which has been carried out under other contracts on free-flow electrophoresis, levitation melting, float-zone refining, etc. has been utilized to stimulate the thought processes of potential Users during this Study. Many such Users will maintain and, likely, increase their interest, if an on-going research program demonstrates NASA's continuing interests.

Users will not only take note of the current researches mentioned above, but will be more inclined toward direct involvement if the specific materials, phenomena, or processes noted in their identified ideas of this Study should be the subject of those experiments. For example, should levitation melting experiments continue, then, as noted in Idea No. 30, High Purity Tungsten X-ray Targets, and Idea No. 60, Amorphous Glasses and Oxides, test specimens should be tungsten, glass and certain specific oxides.

Perhaps the most important research implications of this Study, however, are those that reflect previously uninvestigated areas such as the particle manipulation of Idea No. 3, or the low vibration processes of Ideas No. 1 and 5. Initial research in these areas could, possibly, expand the number of potential space processes considerably.

Our Study also has uncovered the need for very basic data in two areas which may have wide applications. The basic heat transfer data for Idea No. 84, and the physiological response data for Idea No. 96 are more research-oriented than applications, but Users are reasonably certain of the potential benefits that could accrue from such data.

In summary, it is felt that the Study has, as part of the overall effort, engaged in the type of speculation that generally asks more questions than it answers, but that the unanswered questions point the way to research which can lead, eventually, to new products, processes, and services.

VIII SUGGESTED ADDITIONAL EFFORT

During the Final Presentation on Phase I to the NASA Advisory Group for this Study, a key recommendation of the group was made:

"Don't stir the pot, and not follow up"

This was further elaborated upon with two specific statements:

1. Consider the possibility of maintaining and extending User contacts.
2. Consider analyzing the next level of Study Ideas.

The message here is that we have promoted the participation of about a dozen User organizations, and the interest of, perhaps, several times that number, in space as a business-expanding medium. If we allow that momentum to die, this representative sample of industry will lapse back into an apathy that could inhibit the next era in space – its exploitation. The recommendation, thus, is to continue that participation and interest. Several alternatives logically present themselves as possible follow up efforts:

1. Continue the Phase I type of effort, seeking more possible Users. Such a course, however, does nothing to continue the interest of the already participating Users.
2. Initiate a Business Planning Effort with Several Users. The intent here would be to demonstrate to the Users and to NASA, the specifics of technical, resources and marketing plans required to transfer typical space-developed or -produced items from the concept and experimental stages to actual consumer use. By establishing the key decisions and their timing, and by defining the NASA/Industry relationships that must be resolved for such a program, it may be possible to overcome the initial trepidation commercial industry has exhibited in the questions noted in Section VI. Such a study, however, contributes only slightly to the technical understanding of the Ideas generated during Phase I.
3. Develop experiment requirements and planning data for selected Ideas. This compromise approach could provide both technical and planning data. By limiting the number of ideas investigated, and the depth of planning analysis, a useful study of limited scope can be accomplished relatively inexpensively. This third alternative has been accepted by the NASA C.O.R., and the follow-on has been initiated. The objectives of the Phase II Study are pictured in Figure 25. More detailed information on Phase II may be found in the Phase II Study Plan, dated December 1, 1972.

FOR FOUR SELECTED IDEAS FROM PHASE I:

- SELECTION OF BEST APPROACH FOR IMPLEMENTATION OF EACH IDEA
- DEFINITION OF REQUIREMENTS FOR EXPERIMENTS TO VERIFY SELECTED APPROACH - INCLUDING MISSION PROFILES, TYPES OF VEHICLES AND GROUND FACILITIES
- ESTABLISHMENT OF TECHNICAL, TIMELINES AND MILESTONES TO ACHIEVE OPERATION (PRODUCTION, OR SERVICE) OF PROTOTYPE FACILITY/ PILOT PLANT
- FORMULATION OF PLANNING PROFILES TO RELATE KEY MANAGEMENT DATA TO TECHNICAL TIMING. DATA TO INCLUDE DEVELOPMENT STEPS, DECISION POINTS, ALTERNATIVES, RISKS, MAJOR FACILITIES, UNIQUE MANPOWER.

Figure 25. Phase II Objectives

FOLDOUT FRAME 1

FOLDOUT FRAME 2

KEY IDEAS FOR PRODUCTS, PROCESS, SERVICES IDENTIFIED IN PHASE I B.U.S. STUDY

IDEA NO.*	TITLE	DESCRIPTION
1.	IMPRINTING CIRCUITRY ON CRYSTAL WAFERS FOR SURFACE ACOUSTIC WAVE (S.A.W.) ELECTRONICS	PRODUCTION OF PRINTED S.A.W. CIRCUITS WITH $\lambda/4$ TO $\lambda/2$ SPACING FOR $\geqslant$30 GHz OPERATION. REQUIRES ISOLATION FROM SEISMIC AND ACOUSTIC COUPLING VIBRATION
3.	PARTICLE MANIPULATION BY SMALL FORCES	SEPARATION, REMOVAL, INSERTION, EMPLACEMENT AND DEPOSITION OF $\approx$MICRON SIZE PARTICLES, WITH AND WITHOUT VISCOUS MEDIA, BY SMALL FORCES OF ELECTROMAGNETIC RADIATION, PARTICULATE RADIATION, SOUND WAVES, MAGNETIC AND ELECTROSTATIC FORCES, ETC.
5.	VIBRATION TESTING OF SMALL MOTORS	DYNAMIC VIBRATION TESTING OF FRACTIONAL HORSE POWER ELECTRICAL MOTORS DECOUPLED FROM GRAVITY ENVIRONMENT FOR BEARING, LUBRICATION AND STRUCTURAL DESIGN IMPROVEMENTS TO OBTAIN LONGER LIFE.
6.	SINGLE CRYSTAL AND EUTECTIC HIGH TEMPERATURE TURBINE BUCKETS	GROWTH OF SINGLE CRYSTAL AND EUTECTIC TURBINE BUCKETS WITHOUT ANOMALIES FOR $>1650^{0}$C TURBINE INLET TEMPERATURE AND MINIMIZED GRAIN BOUNDARIES FOR INCREASED BUCKET LIFE.
30.	HIGH PURITY TUNGSTEN TARGETS FOR X-RAY TUBES	LEVITATION MELTING AND REFINEMENT OF TUNGSTEN TO REDUCE GRAIN BOUNDARIES, INTERSTITIAL IMPURITIES, PARTICULARLY OXYGEN AND CARBON, FOR LONG LIFE X-RAY TUBE TARGETS
42	PRECISE SEPARATION OF RADIOISOTOPES	APPLICATION OF SMALL FORCES, LIGHT, SOUND, MAGNETISM, ETC., TO SEPARATE RADIO-ISOTOPES BASED UPON DIFFERENCES IN EFFECTIVE CROSS-SECTIONAL AREAS, DENSITIES, SIZES, MAGNETIC AND ELECTROPHORETIC AND DIELECTROPHORETIC SUSCEPTIBILITIES, AND THEIR RESONANCES TO RADIATION PRESSURES.
46.	SILICON CRYSTAL GROWTH FOR POWER AND MEDICAL APPLICATIONS	GROWTH OF MORE PERFECT SILICON CRYSTALS >7.5 CM DIAMETER IN SPACE FOR ELECTRICAL POWER RECTIFICATION AND FOR RADIOLOGICAL SENSORS AND X-RAY CAMERAS.
59.	EPITAXIAL CRYSTAL GROWTH OF MAGNETIC BUBBLE MEMORIES	GROWTH OF SINGLE CRYSTAL GARNET FILMS UNDER MINIMUM CONVECTION WITH UNIFORM ($\pm$ 1%) THICKNESS AND MAGNETIC PROPERTIES FOR COMPUTER MEMORY DEVICES.
60.	AMORPHOUS OXIDES	CONTAINERLESS MELTING AND MINIMIZED CONVECTION TO PRODUCE AMORPHOUS FORMS OF OXIDES THROUGH ISOLATION FROM CONTAMINATION AND SOURCES OF NUCLEATION TO PREVENT DEVITRIFICATION.
84.	THERMAL CONDUCTIVITY OF LIQUIDS	MEASUREMENT OF THERMAL CONDUCTIVITY OF LIQUIDS FOR MATERIALS OF LOW THERMAL DIFFUSIVITY TO ELIMINATE ERRORS ($\approx$25% FOR OILS DUE TO CONVECTIVE CURRENT VELOCITIES OF $\approx$ 0.015 CM PER SECOND).
89.	SEPARATION OF ISOENZYMES	LARGE-PORE GEL ELECTROPHORETIC SEPARATION IN SPACE OF LARGE BIOLOGICAL MACRO-MOLECULES TO OBTAIN SPECIFIC ISOENZYMES WHICH WILL FACILITATE PREPARATION OF SPECIFIC ANTI-BODIES FOR MEDICAL DIAGNOSIS AND IMMUNIZATION.
96.	UTILIZATION OF BIORHYTHMS	DETERMINE THE EFFECTS OF EXOGENOUS STIMULI ON THE CIRCADIAN BIORHYTHMS OF MAN IN SPACE (AND SMALL MAMMALS) FOR UTILIZATION ON EARTH TO ALLEVIATE TRANSMERIDIAN DYSCHRONISM, EFFECTS ON ROTATING SHIFT WORKERS, AND FOR MEDICAL AND PUBLIC HEALTH USES.

*NUMBERS ARE FOR EASE IN DATA HANDLING ONLY.